



88079047

An Applications Guide for Surface Hydrologic Terrain Analysis in ARC/INFO

Version 1.0
May 1997

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by

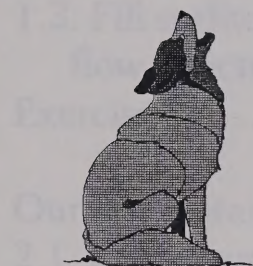
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Easy conventions

Introduction 7



An overview of concepts



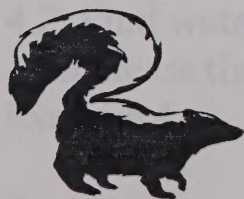
A note of relevance



An ARC command



Retrieve on-line help information



A warning



An exercise

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Introduction

The Bureau of Land Management, as well as other Department of the Interior agencies, has been mandated to adopt an ecosystem-based approach to managing lands and their natural resources. One of the major issues involved is agreeing on how to map ecosystem boundaries and whether such mapping possible at all. The main difficulty is that ecosystems can be defined at a variety of scales and viewed from a variety of perspectives.

In a very real sense, the entire Earth is a single ecosystem; quite possibly, definite ecosystem boundaries can be defined with any accuracy only for the entire planet. Ecosystems need not have discrete linear boundaries; they can overlap, interfinger, or grade into each other. For some aspects of an ecosystem, the boundary might be sharp, while for others it could be graded or patchy. Finally, ecosystem boundaries are always in some degree of flux as they change with varying climatic conditions.

For many years, the main issue for cartographers or map-making scientists has been how to make a map as accurate as possible in its representation of reality. A map is a representational model of some geographically distributed property of physical reality. A representational model can be defined partly as a symbolic or iconographic model of geographically distributed phenomena, and partly, especially in automated spatial data processing context, a relative of a physical model

in its maintenance of scale relationships between the real and mapped objects.

The reason that a map is a model rather than a mere representation, like a photograph, is because it involves translation of geographic phenomena and their inter-relationships into an interpreted form such as a point, a line, or an area. For example, what properties of a phenomenon called soils do we use to map soils, or what criteria do we use to identify boundaries between landforms in morphologic maps? An essential question in mapping boundaries for such complex phenomena as ecosystems is what are the criteria we will use and interpret so as to map the approximate locations of ecotones, i.e., areas of change from one ecological structure to another. We also need to ask how well our model reflects actual ecosystems (to the degree we understand what they are) and what it tells us about ecosystems.

One of the basic requirements of geographic analysis and modeling of ecosystems, a naturally multidisciplinary venture, is to decide on a geographic unit that is common to and utilized in different scientific disciplines. Such a unit will not only connect the analysis to an actual location but will also facilitate a multidisciplinary approach to ecosystem analysis.

Traditionally, spatial analysis in ecological research has utilized two types of geographic units: the grid cell and the watershed. The grid cell approach involves using an equal-area grid placed over the project site to divide it into equal quadrats. Qualitative and quantitative descriptions of what scientists can find within the quadrat, including geology,

landforms, hydrography, soils, vegetation, etc., are summarized over the area of each cell and become that cell's attributes. This method is directly related to grid cell modeling in Geographic Information Systems. The main benefit of the quadrat method is that each study site is of equal area and therefore is readily comparable to any other site, removing the *area* variable from consideration, as well as the fact that random sampling of the gridnet always results in picking the unit of the same size. In the grid cell approach there are no limitations on where to place the boundary of the grid, and a grid can be used to subdivide for analysis any portion of the Earth's surface.

The watershed unit approach has been applied successfully by ecologists in studies of ecosystem dynamics. The reason a watershed forms a natural ecosystem analytic unit is because all watersheds have a common geomorphologic property: they collect rainfall throughout their surface area, and then either store this precipitation in the aquifer or soil, or transfer it into the stream where it leaves through the watershed outlet. These properties permit modeling of the hydrologic cycle using watersheds as geographic analytic units as the various aspects of the cycle affect the availability of moisture and nutrients for plant growth within the drainage network-watershed system.

Morphologic characteristics of basins are the reason why watersheds were initially used for ecosystem studies. They provided valuable information (that was also utilized in nonwatershed-based analysis) from the purely hydrologic viewpoint of water balance to studies of nutrient depletion based on measuring leached nutrients at the watershed outlet. Watersheds have always been useful for analyzing the response of ecosystem components to human-caused distur-

balance of the watershed through a "reading out" of the change in quantity and chemical quality of water draining out of the system. Furthermore, watersheds remain an analytic unit for a spectrum of disciplines, including geomorphology, hydrology, ecology, etc., providing a spatial reference for studying the interaction of physical, biological, and chemical processes, as well as economic and social aspects as they are relate to water distribution and natural resource management issues.

Acknowledging the value of watersheds it needs to be added that mini-watersheds (catchments, basins) have the same properties as watersheds, and can be treated as such. Beyond the limitations of the largest and the smallest possible watershed on the planet (from hundreds of miles to tens or hundreds of feet) the terms "watershed" and "mini-watershed" are relative to the scale of usage and will be treated as such for most of this text. However, there exist draft guidelines for watershed delineation that attempt at standardizing watershed hierarchy and are attached in Appendix A for your review (BLM Information Bulletin, 1996).

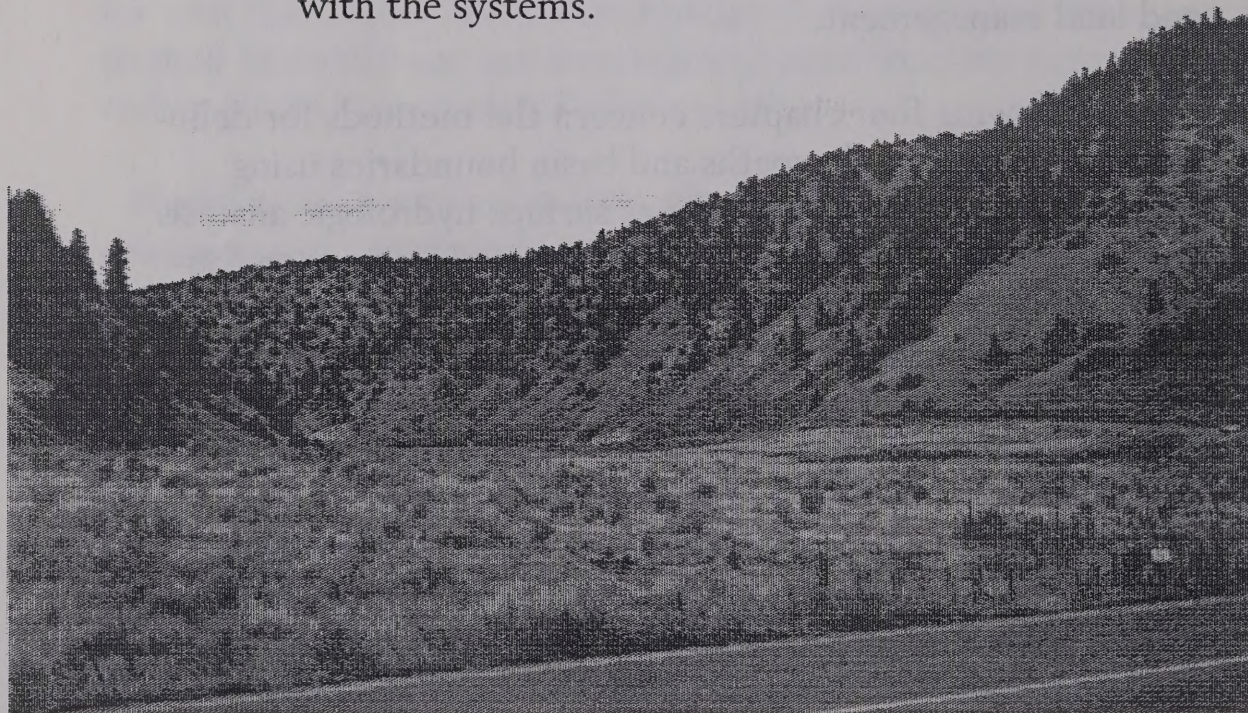
Modeling of, for example, the effects terrain on ecological processes using watersheds as analytic units requires partitioning of the watershed area into mini-watersheds with similar terrain morphology. Large watersheds usually contain large variations in topography, so if in our model we want to keep topographic variation very much the same throughout the site we should choose a small watershed unit. The benefit of using mini-watersheds for analysis is not only in the fact of using an area with similar terrain morphology throughout, or that the site is smaller and more manageable, but also because it is now easy to use GIS to delineate basins in a

variety of ways. Beyond being able to delineate and analyze the watershed in terms of GIS, mini-watersheds can also be small enough to be easily investigated with field sampling and surveying techniques. Therefore using such units permits integration of field, digital cartographic, and remote sensing data and understanding of their relationships in terms of watershed modeling. Potentially information analyzed for one mini-watershed can be extrapolated to other similar basins where field data is not available. In that way large areas could be analyzed using few representative mini-watersheds.

Why bring this up at all? Because it is important to understand the value of automated watershed delineation not only to help delineate watershed units in the traditional way, fitting them into a prescribed watershed hierarchy, but to use the full flexibility of automated systems to delineate units of sizes required for various kinds of detailed resource analysis and land management.

The following four chapters concern the methods for delineation of complete flowpaths and basin boundaries using automated techniques available as surface hydrologic analysis capabilities in the ARC/INFO Geographic Information System. This is followed by a chapter describing upcoming capabilities which will permit us to obtain further information from the watersheds we have delineated. While surface hydrologic terrain capabilities are adequately described in ARC/INFO manuals, it still seemed important to provide tips and additional capabilities for applying these methods basing the information on several years of experience with automated watershed delineation. The Environmental Research Institute's (ESRIs) ARC/INFO GIS system in fact still lacks certain capabilities that were available in the origi-

nal version of the hydrologic terrain analysis software, a set of Fortran programs developed by S. Jensen and J. Domingue in 1988 (these programs were made available as contributed software with the bureau's MOSS/MAPS GIS with manual developed by the author, 1993). The additional capabilities, available as Arc Language Macros (AMLs) on request from the author, can make some types of analysis quicker and easier and their use will also be described in chapter 4 of this applications guide. The author also hopes the reader will enjoy departure from traditional computer icons in the text, done with the goal of preparing a document that is more fun to read than the more formal computer applications guides. It is assumed that the reader has access to ARC/INFO GIS Rev. 7.04 and its online help, and is generally acquainted with the systems.



1. Prepare terrain data

1.1. Digital terrain data for surface hydrologic modeling.



The most commonly used base map for resource analysis is the USGS 7.5 minute quadrangle topographic map, and the most commonly used digital terrain data are contained in the USGS 7.5-min quadrangle Digital Elevation Models (DEMs). The models are computer files that contain information on the location (row, column) and value contained in cells of a grid, an imaginary square cell net drawn over the landscape. Each cell of a DEM is 30 m x 30 m in size, which is equivalent to approximately .224 acres. All variation in topography within that area is represented by a single elevation value. The accuracy of that value is said to have 7 - 15 m root mean square error.

While driving through any terrain try to imagine how much variety of shape is included in an area approximately 100 by 100 feet and you will be able to understand better the limitation of using that resolution. If you are in the flatlands there is hardly any difference in terrain shape from cell to cell, but the moment you find yourself in high relief areas you realize how much variety of landform is lost through the filter of one value per 900 square meter area.

However, based on comparisons with vector stream data available as the USGS Digital Line Graphs, flow path models based on 30 m DEMs are remarkably accurate as is demonstrated in figure 1. However, the algorithms have problems delineating flow paths or watershed boundaries in the flatlands where the software generally tends to draw straight lines.

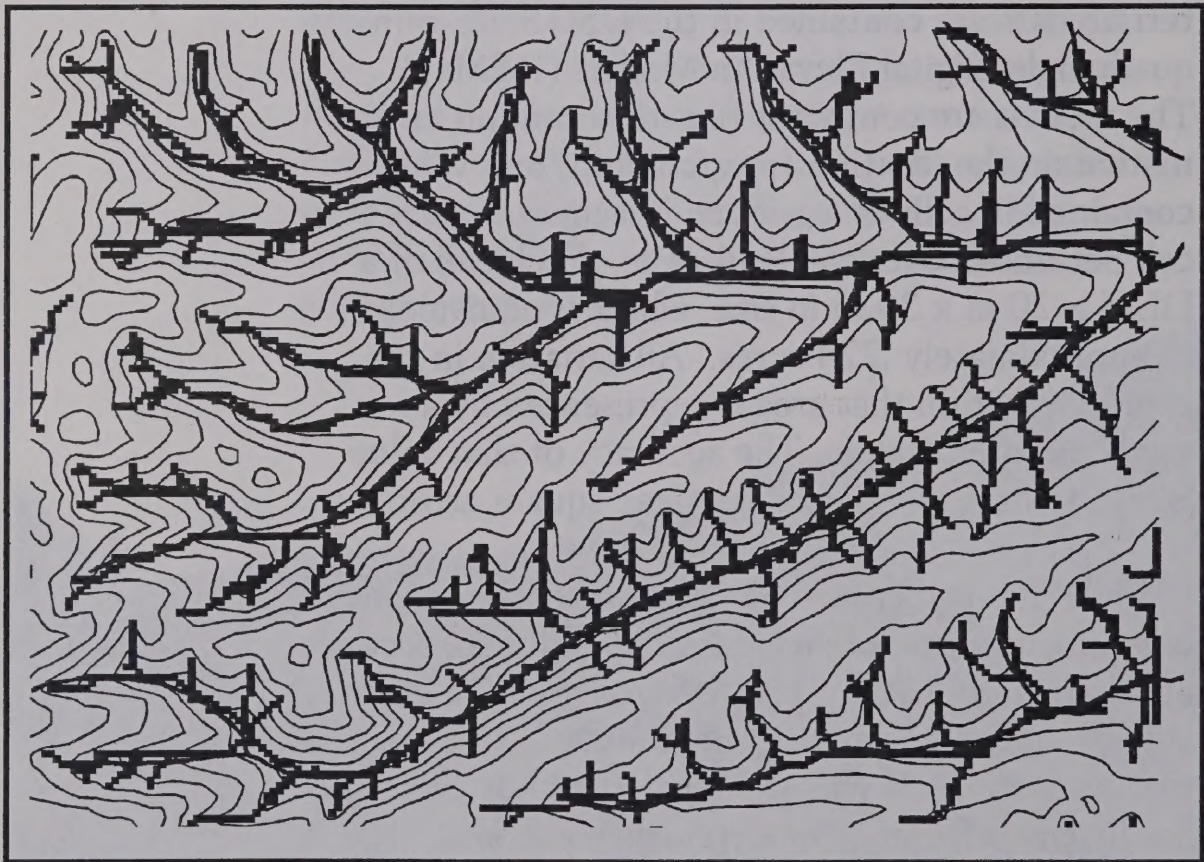


Figure 1. Modeled streams, streams from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

From these facts we can draw a general working hypothesis: that the approximate location of stream flow in high relief areas is controlled mostly by changes in terrain that occur at a geographic scale larger than a 30 m x 30 m cell. For lowlands, however, higher vertical resolution of data is necessary to identify changes in topography that fall below the threshold of the horizontal and vertical resolution of Digital Elevation Models and have influence on surface flow. On very flat areas the location of the stream is controlled more by factors related to microrelief, including soil properties and vegetation cover, and therefore the stream course is impossible to predict based on elevation data. Therefore it appears that thirty meter DEMs are actually adequate for most flow path and watershed modeling efforts in areas where there is a reasonable amount of relief, which is very helpful because almost all available 7.5 minute DEMs have thirty meter resolution and that data is available for almost the entire United States.

We could also look at the coarse resolution of elevation model data as a benefit rather than a problem. It is difficult to use higher resolution data because of the increased size of files and length of processing, and for many applications it is highly unlikely that a higher resolution of data is needed. As our secondary working hypothesis, we should assume that when we have a relatively new DEM which doesn't seem to contain obvious artifacts, such as straight lines, we essentially have an information filter which permits us to look at

various natural objects and processes at a certain scale. That scale can be loosely defined as including topographic features (and their effects) that are larger than .224 acres or about 100 ft square up to any level that DEMs can be practically aggregated to, including the continent.

Any topographic features identifiable from DEMs need to be large enough to contain two points at least 30-42.46 meters (98.4-139.27 ft) apart (the straight and diagonal distances between the centers of two adjacent cells). However this limitation does not mean that we can't logically infer what processes are occurring at a larger, more detailed scale of observation. A particular slope gradient derived from a DEM, although only a very approximate measure, can imply



something about the general movement of soil particles once they become detached from the substrate, and therefore something about the soil erosion potential of a given area. GIS processing also does a reasonably good job of approximating the direction and location of flow and the location of watershed boundaries on the landscape.

1.2. Merge and edit DEM data



To delineate flow paths and watersheds from DEM data you will first probably need to edit the data by eliminating quadrangle joint areas consisting of cells without any data. These sometimes appear when you are working with more than one DEM and then try to merge the DEMs together. To merge DEM grids in ARC GRID use the merge command:



mrgdDEM = merge (DEM1, DEM2, . . . DEMn)

Lack of complete match at the DEM edges can cause large, straight, and narrow linear features to develop where the DEMs have been merged. These gaps in elevation values are properly identified in the merged DEM grid as NODATA cells.

One way to deal with this problem is to create a neighborhood around the NODATA cells and using the neighborhood assign some value to the NODATA cells. In the following example the new value is the average or mean of the values of the cells in the neighborhood.

The smallest possible neighborhood in a cell map consists of eight cells surrounding the central cell. In designing a command to fix the NODATA data gaps in a DEM we first need to test whether

a particular cell is a NODATA cell, and then assign the mean of the neighborhood to it.

tempDEM = con (isnull(mrgdDEM),focalmean ~ (mrgdDEM), mrgdDEM)



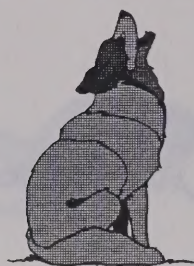
The **CON** statement looks through the merged DEM to check if a particular cell it is looking at is a NODATA cell (**isnull(mrdgDEMgrid)**). If that condition is TRUE, the function **FOCALMEAN** is invoked and calculates the mean or average value of the eight cells surrounding the NODATA cell, then assigning the mean value to the NODATA cell (**focalmean (mrgdDEMgrid)**). If the condition is false then the values in the DEM are left as they are, and the **CON** statement looks at the next cell in the grid (mrgdDEMgrid).

If we review our DEM file and see that all the NODATA cells have been filled with average values from the 3 x 3 cell focal area or a neighborhood, we should change the name tempDEMgrid to a more permanent name, such as editdDEMgrid.

Warning!

We should always visually review our DEM file prior to and after edits. Sometimes when we review our newly edited DEM file we will find that it still contains NODATA cells usually in a form of a linear feature at the boundary between DEMs. This is because the gap between DEMs is greater in width than one NODATA cell.





Note:

There are two ways to deal with the problem of wide NODATA gaps at DEM boundaries. One way is to repeat the above **CON** command again on the grid, creating another temporary grid which is then again reviewed. The process is continued until all the cells are filled. The reason this approach works is because on the first run of the command the multi-celled NODATA area was shrunk by the width of one cell (if the default 3 x 3 cell neighborhood was used).

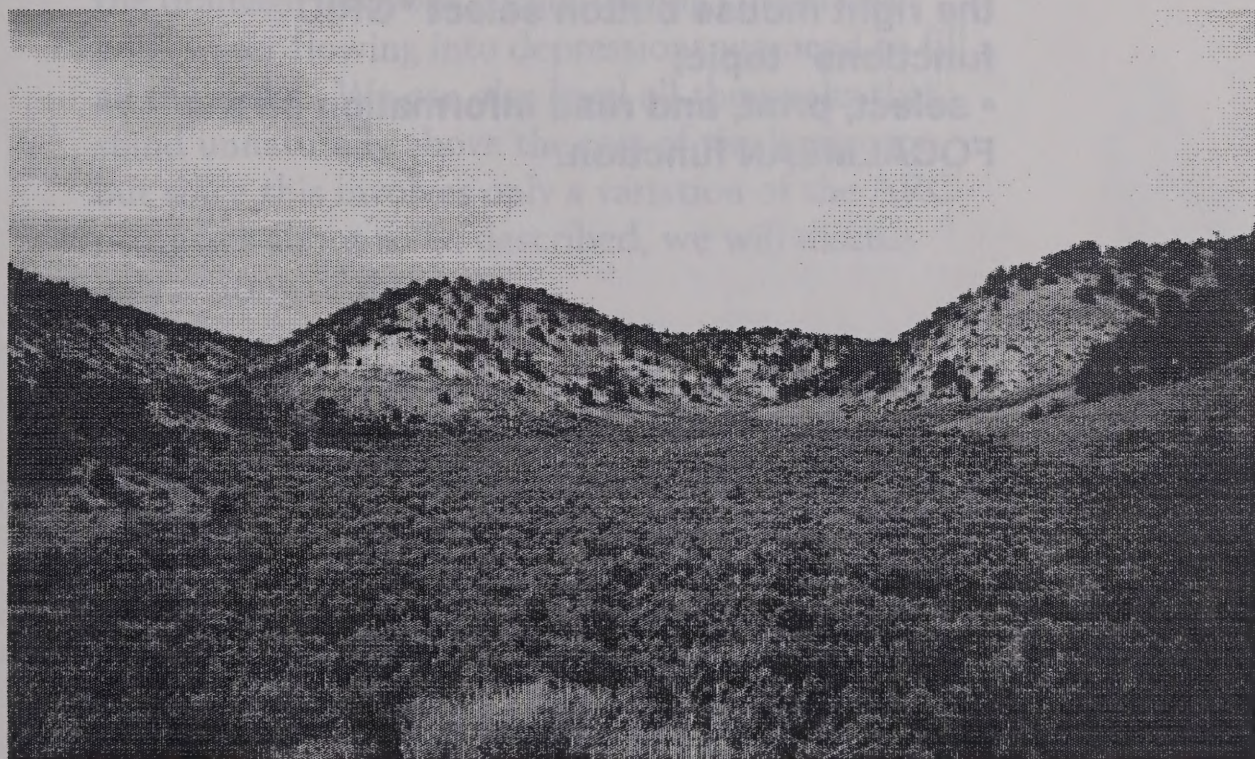
Why? After the first run of the command, on each following run the existing edited DEM is used to create the new edited DEM, which is then used as a source to create another edited DEM. For wide gaps, on the first run when the averaging process reaches a **NODATA** cell surrounded by other **NODATA** cells (within a 3 x 3 cell neighborhood), not having any data it cannot calculate the average and leaves that cell as **NODATA**. On the following runs it uses the product of the preceding run in which the gap has been shrunk by previous processing. In that way the area containing data is grown in each consecutive run of the **CON** statement until the gaps in data are completely filled.

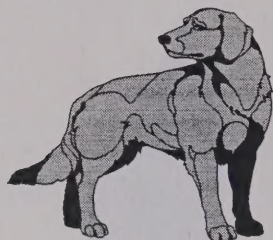
Although this process can be work-intensive (you can write an **AML** to do it as string of repeated **CON** statements) it produces the best results, because using a 3 x 3 neighborhood limits the degree of smoothing by considering only the

nearest cells as the source of values. Therefore this edit brings the DEM closest to it's likely natural condition.

An alternative is to use the **CON** statement with a nested **FOCALMEAN** function that uses a larger neighborhood. Although in this way you can edit the DEM more quickly, this approach will introduce more smoothing into the edited DEM. Following is an example of the **CON** statement which utilizes a **FOCALMEAN** function with a 10 x 10 cell neighborhood.

```
editdDEM = con (isnull(mrgdDEM),  
focalmean (mrgdDEM, rectangle, 10, 10),  
mrgdDEM)
```





To retrieve on-line help information for related topics:

- when the Table of Contents appears click on the “Cell Based Modeling with GRID” topic;
- select, print, and read the “Conditional and individual-cell processing” topic and also print “Surface hydrologic analysis” topic for later reference;
- go back to the Table of Contents and holding right mouse button select “GRID statements” topic
- select, print, and read information on the CON statement;
- return to the Table of Contents and holding the right mouse button select “GRID functions” topic;
- select, print, and read information on the FOCALMEAN function.

1.3. Fill surface depressions and calculate flow direction.

In the natural terrain flow paths can lead to depressions or sinks in which they end. Thus natural depressions have their own catchments. Secondly, some DEMs contains errors which result in unnatural peaks or sinks in the model that are not representative of the terrain. While the natural depressions are usually multi-celled, the peaks and sinks that are DEM artifacts are usually single-celled, except possibly in regions with karst geomorphology.



To be able to calculate watersheds that represent the drainage network without being concerned with water flowing into depressions we need to fill all the sinks. We can also level all the peaks that stand unnaturally above the rest of the landscape, but since this involves only a variation of the ARC processes about to be described, we will discuss only editing of the sinks.

To find out if we have any single-celled sinks we should run the **FLOWDIRECTION** command on the unfilled DEM. If the product of this process, a flow direction map (in which a direction of flow along the steepest path is assigned to each cell of the DEM), contains locations where two cells flow into each other, the direction of flow at these locations will be undefined. To run the

flow direction analysis process on the DEM use the following syntax.



flodirorig = flowdirection (editdDEM)

Now to find out the location of all the sinks, and have each sink receive it's own number (from one to the total number of sinks), use the **SINK** function which will identify all the sinks, or areas of internal drainage.



sinkmap = sink (flowdirorig)

or

sinkmap = sink (flowdirection(editdDEM))



Note:

The second version of the command above simply demonstrates that in ARC GRID functions can be concatenated or combined together by nesting functions within other functions. We've encountered this before in the discussion of the CON statement for editing merged DEMs. We can create a sinkmap by nesting the **FLOWDIRECTION** function within the **SINK** command. We can do this with most other GRID functions as well.

Since for most of my surface hydrologic processing I haven't needed an numbered map of sinks I usually take a more direct approach to

preparation of the DEM data by assuming from the beginning that the DEM will contain some single-celled and multi-celled depressions. Therefore my goal is to immediately obtain a DEM which has all the depressions filled. To do so I use the FILL.AML, a program which automatically fills all the sinks and which is directly accessible from GRID.

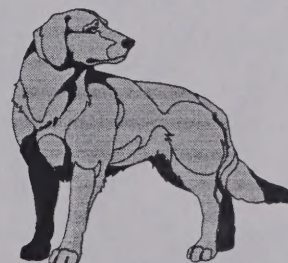
filldDEM = fill (editdDEM, sink)



By filling all the depressions the **FILL** program creates a DEM in which all the cells can be assigned a flow direction value that is *part of a continuous path which flows toward the edges of the data set*. At that point the **FLOWDIRECTION** function is used again to create a flow direction map that can be used to delineate watersheds which are part of the stream network for the study area.

To retrieve on-line help information for related topics:

- In ARC type "HELP"
- when the Table of Contents appears click on the right mouse key and select: Grid functions *topic*.
- Go to the letter "F", select, and print information on the following functions:



FLOWDIRECTION and FILL.

- Go to the letter “S”, select, and print information on the function SINK.
- On page 7 of the “Surface hydrologic analysis” paper obtained previously, compare information you just learned with the flow diagram.



Exercise 1. How to analyze terrain for closed basins

Although quite often sinks in a DEM are artifacts, until we verify that this is so we should maintain information about them. If they represent naturally formed closed basins they are important as sedimentation traps or areas of standing water and potentially aquifer recharge locations. The following exercise will demonstrate how to develop a map of closed depressions for the study area. To begin with use FILL.AML to fill all the sinks.



fill editdDEM filldDEM sink

We now have a DEM in which the surface of all the depressions has been raised to elevation of the surface of nearest neighbor cells that are not part of the depression. To obtain a map of depressions or closed basins we subtract the original unfilled DEM from the filled DEM.



sinklenses = filldDEM - editdDEM



Figure 2. Closed basins, mostly falling along the streams obtained from the 20 m contour lines for a portion of the Sagbrush Hill USGS 7.5 minute quadrangle.

SAMPLE FILE DESCRIPTION:

Grid: describe sinklenses

Description of Grid /TERRA/COLORADO/WOLSAG/SINKLENSES

Cell Size =	30.000	Data Type:	Floating Point
Number of Rows =	149		
Number of Columns =	193		

BOUNDARY

Xmin =	703371.125
Xmax =	709161.125
Ymin =	4420640.000
Ymax =	4425110.000

STATISTICS

Minimum Value =	0.000
Maximum Value =	14.000
Mean =	0.052
Standard Deviation =	0.539

COORDINATE SYSTEM DESCRIPTION

Projection	UTM
...	

Our new sinklenses map now contains information about the depths of our depressions, which, in this case, do not exceed 14 meters. From this information one could design methods for analyzing the volumes of depressions (which will not be discussed in this document). It is also possible to delineate watersheds for the depressions, but first we need to have each depression identified with a unique number (which will later correspond to the number of the watershed delineated for the depression). To do so we need to turn our floating point sinklenses map into an integer map.



sinklensesi = int (sinklenses)

We now have an integer map showing the depth of the sink lenses. The next step is to assign a unique number to each sink, i.e. a region of adjacent cells that represent a closed basin or a depression.



Figure 2. Closed basins, mostly falling along the streams obtained from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

To assign unique value to each sink we use the **REGIONGROUP** function as follows:



sinkregions = regiongroup (sinklensesi)

SAMPLE FILE DESCRIPTION:

Arc: list sinkregions.vat

Record	VALUE	COUNT	LINK
1	25507800	28342	25507800
2	97200	2	97200
3	49500	1	49500
4	97200	1	97200
5	27900	1	27900
6	40500	1	40500
7	76500	2	76500
8	18000	1	18000
9	29700	1	29700
10	76500	2	76500
11	76500	1	76500
12	49500	1	49500
13	49500	1	49500
14	97200	1	97200
15	27900	1	27900
16	29700	1	29700
17	49500	1	49500
18	97200	2	97200
19	97200	1	97200
20	49500	1	49500
21	97200	1	97200
22	76500	1	76500

Continue?

2. Our first watersheds

2.1. Create watersheds based on terrain ridges.

One obvious way to delineate watersheds (catchments, basins) is to look at ridges that separate the basins and identify all the cells interconnected by their flow direction that fall within the ridges. Where ridges are located the flow directions of adjacent cells will be pointing away from each other, while within the basin the flow paths will confluence onto a central stream forming a drainage pattern. To analyze watersheds in this way we have to use the ARC GRID **BASIN** function which uses the flow direction map to identify both the connections between flowpaths and the ridges to automatically produce a map of watersheds.



ridgbasorig = basin (flodirorig)

or

ridgbasfilld = basin (flodirfilld)



The first example above shows application of the **BASIN** function to the original flow direction map made from an unfilled DEM. The second example shows the same function used with a filled DEM.



WARNING!

We should remember that the original unfilled DEM might be more representative of actual terrain conditions and therefore we should always retain a copy of it on file.

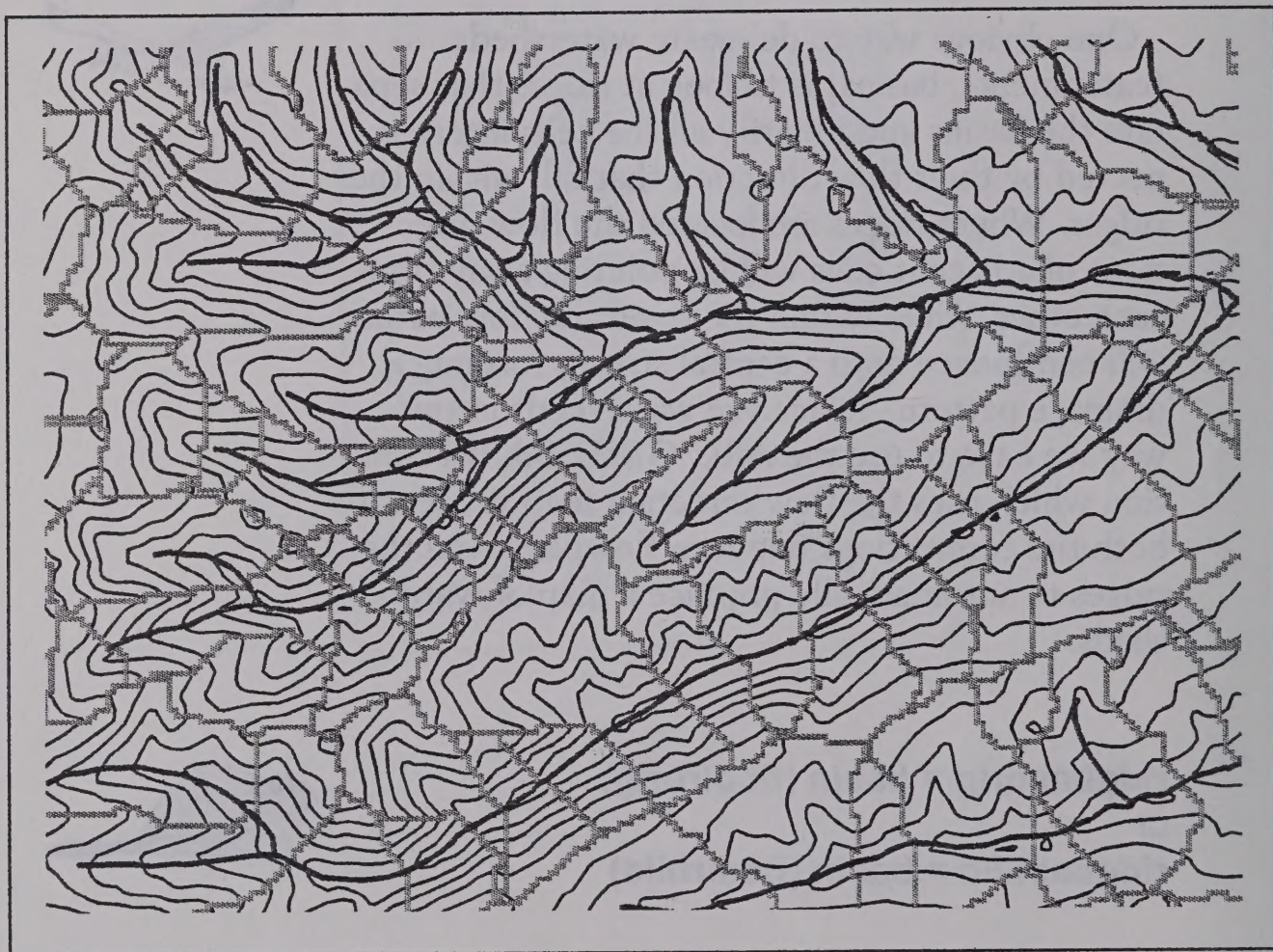


Figure 3. Watersheds derived using the **BASIN** function of ARC GRID applied to an unfilled DEM, streams obtained from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

2.2. Grow watersheds from their outlet location.

Another way to identify watersheds from terrain data is to identify outlet locations for which you want to delineate basins. Such outlet locations could be a natural outlet point for a watershed, a linear feature such as a dam, or an areal feature such as a lake or a depression. Once we have decided on the outlet locations and specified it in a new grid map, we can use the **ARC GRID WATERSHED** function to find all the cells that contribute flow to this location using the flow direction grid. The function traces all the connected flow cells growing the watershed “backwards” from its outlet.



Using the simplest example, we can identify an outlet point for which we want to delineate the contributing area with the cursor option of the **GRID SELECTPOINT** function. Before we do that we should first window on and display some version of the DEM data, perhaps a contour map made from it (discussed in the next section) or a stream map for the area. Then we proceed.

```
outlets = selectpoint (fillddem,*,inside)  
Define the points <9 to END>
```



The asterisk means that a cursor will appear on the display permitting an interactive visual selection of

points, the locations of which are written into the grid outlets. The key word **inside** indicates that only the points clicked on within the window of the map will be written to the new grid. Once we have created the outlet point grid, we now can use the **watershed** function to delineate catchments for the outlet points.



watersheds = watershed (flodirfilld, outlets)

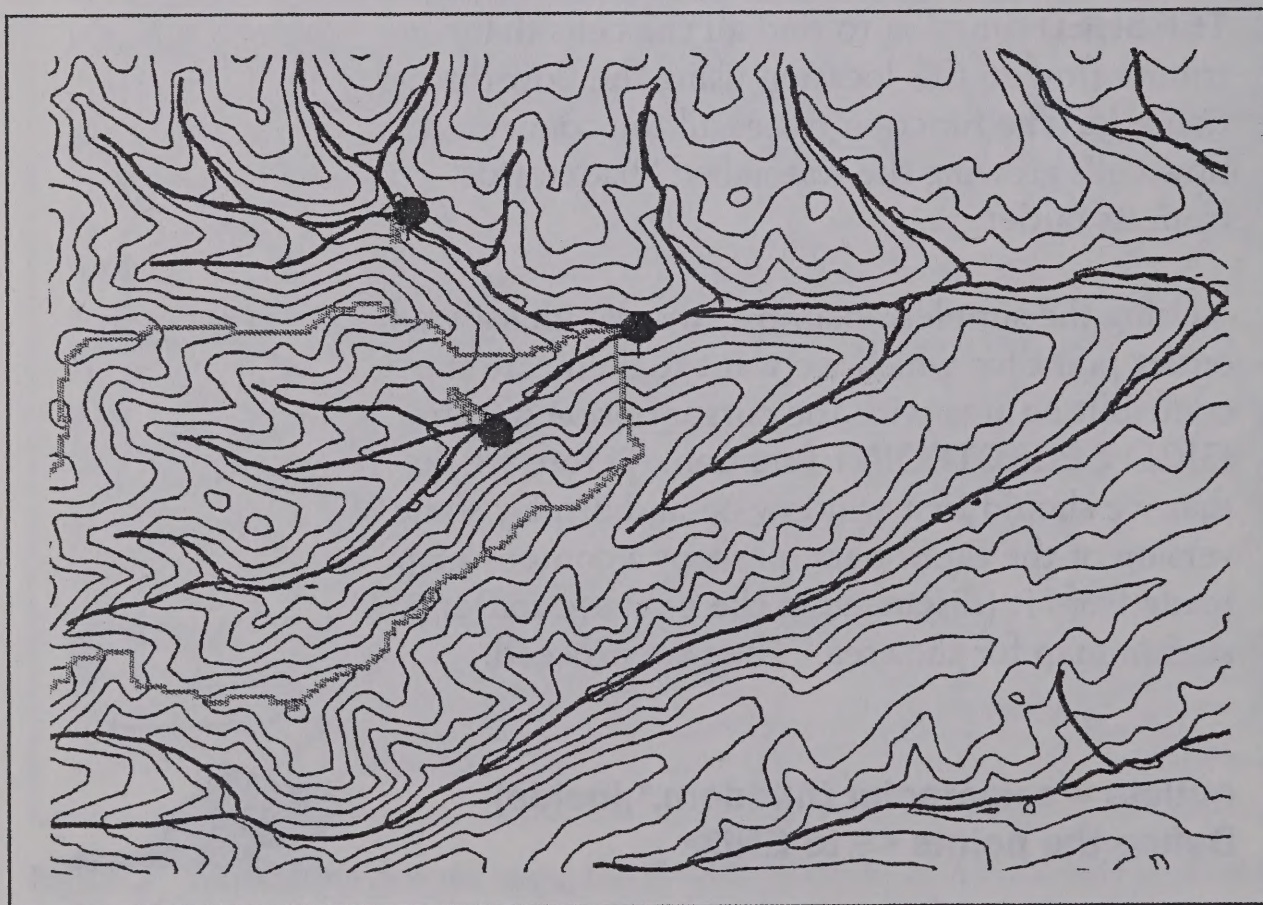


Figure 4. Watersheds derived for three outlet locations (placed randomly on streams) with the **WATERSHED** function of ARC GRID applied to a filled DEM, streams obtained from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

As we can see on the preceding illustration some of the watersheds delineated are very small. This is because, although we might have done our best to place this outlet on a stream, when we used DLG stream to help us make the selection we missed the location of flowpath on the DEM. As we noticed on figure 1 there is some displacement between the modeled flow paths and the DLG stream data sets. While a large number of cells are connected to the cell on the flowpath, that is not true of the cell adjacent to the flowpath. Since the **WATERSHED** function calculates watersheds using flow direction map to include all the cells flowing to a particular cell, the watershed for a cell adjacent to the flowpath is very small because only a few cells flow into that cell. ARC GRID contains methods to deal with this problem which will be discussed later in this guide.

2.3. Display watersheds.

To view our results we have to be able to display the watersheds. This can be accomplished simply using the following syntax:



gridshades watersheds
or
gridpaint watersheds

The result will be a display of a watershed map in which the watersheds will be filled automatically with colors from default shade tables.

We might also want to have the grid watershed map converted into polygonal data. To do so in ARC GRID we use the **GRIDPOLY** function as follows:



watershedsp = gridpoly (watersheds)

WARNING!

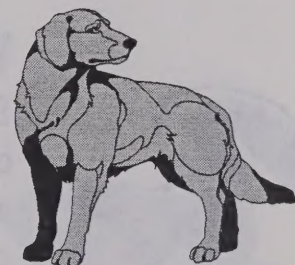
There is a problem with converting watershed maps in the grid format into polygonal maps. Some of the cells that constitute the same watersheds are diagonally linked to other cells, i.e. they are attached by their corners. When **GRIDPOLY** creates polygons out of the same value (i.e. same watershed) cells, it has to consider these diagonally linked cells as separate polygons, giving rise to new "watershed" polygons with very tiny areas.

NOTE:

If we absolutely need to work with polygonal format watersheds that are as close to representing the grid format watersheds in their attributes as possible, we will need to use an area threshold filter to remove diagonally connected cells from the grid watershed map. This can be accomplished by the use of the following **CON** statement.

editdsheds = con (zonalarea (regiongroup ~ (watersheds)) > 10000, watersheds)

The **CON** statement looks through the watershed grid using the following nested commands: first the **REGIONGROUP** function groups each set of cells connected on their sides rather than diagonally at their corners into a zone, and secondly the **ZONALAREA** function determines





the area of the zone. A zone is an integer or discrete cell map category, or, in MOSS/MAPS language, the subject of a type 7 discrete map. If the area of the zone is greater than 10000 it is assigned the value of the watershed, otherwise, by default, it is assigned the value of NODATA. The reason we used the value of 10000 as the threshold is because almost all areas created by diagonally adjacent cells do not exceed more than 7200 square meters. The 10000 value is therefore given to include additional 3 cells with a total value of 9900 square meters which is then rounded off.

WARNING!



Selecting the value of 10000 is merely a convention and should be preceded by as careful a review of the areas created by the diagonally connected watersheds as is possible. The review can be accomplished by **LISTing** the attributes for the polygonal watershed file created using the **GRIDPOLY** function and looking for very small area polygons which have identical "grid-code" item values as other, larger, polygons.

Now we need to replace the NODATA values with real values obtained from the cells that surround and are adjacent to the NODATA cells. To do so we must first create a mask that covers all the NODATA locations, i.e., a grid which contains only NODATA locations from the editdsheds map, but now these locations are assigned some value of our choosing, e.g. -999 or some other

value adequately different from the cell values in our original grid. To create a mask map we begin by assigning the value of -999 to the former NODATA locations using another **CON** statement.

**editdsheds2 = con(isnull(editdsheds), -999, ~
editdsheds)**



The reason we assigned the values of -999 to the NODATA areas is so that now we can extract them. By extracting the -999 values, adequately different from other elevation values, we can now create a grid in which the former NODATA locations are the only values in a grid, now equal to -999, while all the other locations are assigned the value of NODATA.

maskgrid = select (editdsheds2, 'value = -999')

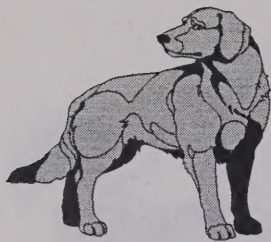


We now have a maskgrid for all the areas which, using gridpoly, would be turned into separate tiny polygonal watersheds. We can use the maskgrid to assign the nearest neighbor value to the NODATA cells in editdsheds effectively assigning the value of the surrounding watershed to the small inclusion of another watershed within it.

editdsheds3 = nibble (maskgrid, editdsheds)



To verify our work we now should convert the map editdsheds3 into a polygonal watershed map using the **GRIDPOLY** function. Then we should use the **LIST** command to list the content of editdshedspat and check on the absence of diagonally connected small areas, as well as verify the correspondence between the "grid-code" item and the "editdshedsp-id" item. They should not be off by more than the value of 1 since the first polygon identification number in a polygonal map is always assigned to the universal polygon which represents the entire area of the map.



To retrieve on-line help information related to these topics:

- in ARC type "HELP"
- when the Table of Contents appears while holding down the right mouse button click on "GRID functions"
- select, print, and read descriptions of the **GRIDPOLY**, **ZONALAREA**, **REGIONGROUP**, **NIBBLE**, **SELECTPOINT**, **BASIN** and **WATERSHED** functions

Exercise 2. Delineate catchments for dams and reservoirs.

An interesting and useful benefit of ARC GRID surface hydrologic terrain analysis capabilities is that they permit us to delineate watersheds for any points or sets of points on the landscape based on the flow direction grid. This might be useful if we are, for example, trying to find the best locations and delineate contributing catchment areas for a sediment retention or detention structure or a reservoir. In this example we used the **SELECTAREA** function in ARC GRID to generate multi-celled areas that represent a dam and a lake.



```
damgrid = selectarea (filddem,*,inside)
```

```
Define the points <9 to END>
```

```
and
```

```
lakegrid = selectarea (filddem,*,inside)
```

```
Define the points <9 to END>
```



Using the cursor draw the extent of dams or reservoirs where you would like to see them located along the streams of the study area. Based on your input the **SELECTAREA** function creates a grid map which can be used as a watershed outlet map. The new outlet map contains the elevation values located within the selected area which can be used for some specialized modeling purposes, but here we will transform the areas into simple univalued objects using **INT** and **REGIONGROUP** functions.



```
damgridi = int (damgrid)
lakegridi = int (lakegrid)
damregions = regiogroup (damgridi)
lakeregions = regiongroup (lakegridi)
```

We now have maps that contain unique values for each dam or reservoir we have interactively drawn for the study area. To obtain watersheds for these objects we use the watershed function.



```
damsheds = watershed (flowdirfilld,  
damregions)  
lakesheds = watershed (flowdirfilld, lakeregions)
```

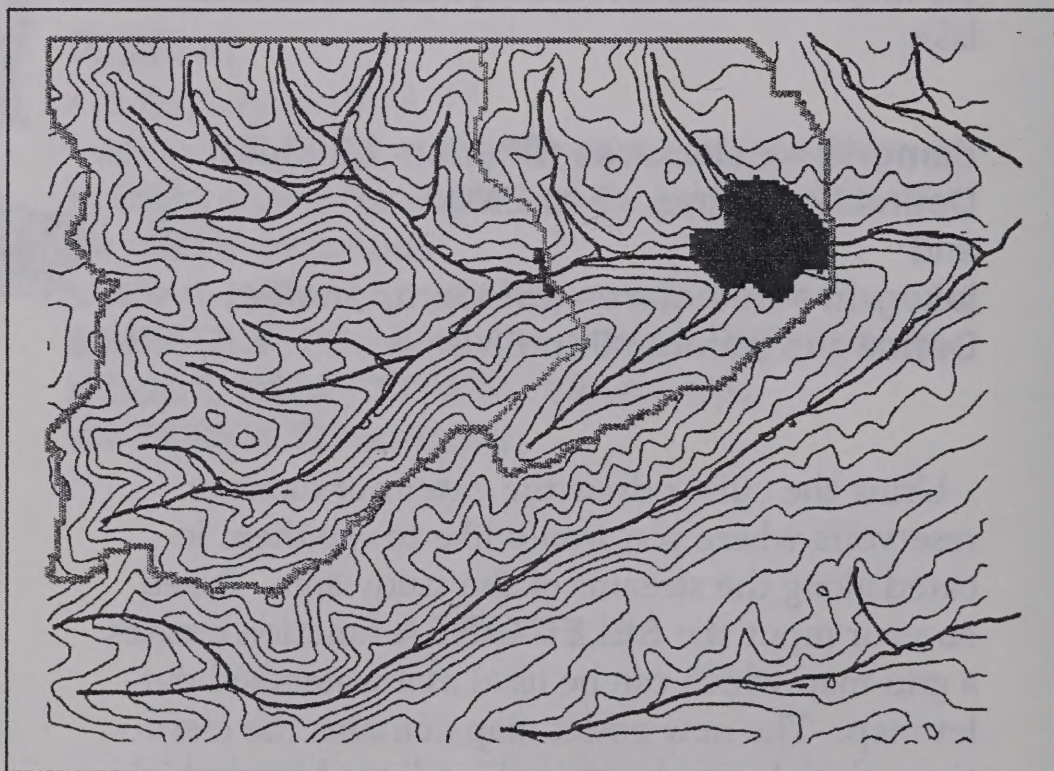


Figure 5. Watersheds derived for a dam and a reservoir (placed randomly on streams) with the **WATERSHED** function of ARC GRID applied to a filled DEM, streams obtained from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

3. Delineate drainage networks

3.1. Count accumulation of flow across the landscape and identify drainage networks.

The directions of flow in the flow direction map created using the FLOWDIRECTION function on a filled DEM make continuous flowpaths to the edge of the DEM. By counting the cells along the paths as they flow into other cells permits us to calculate the flow accumulation count throughout the terrain of the study area. This essentially means that if a cell has another cell flowing into it, its flow accumulation count is 2, if it has 100 other cells flowing into it, its flow accumulation count is 101. The flow accumulation values across the terrain are calculated as follows.



flowcount = flowaccumulation (flodirfilld)



Across terrain water flows toward the lowest points along the steepest paths and instead of remaining a sheet the flow tends to accumulate into streams and channels creating drainage patterns. Interaction of the geology and climate of an area result in terrain morphology that in turn shapes the drainage patterns.

By identifying cells above some threshold level (essentially a value for the amount of flow accumulation) we discover that the cells clearly outline hollows, channels, and streams of greater and greater order. As has been previously observed, drainages derived from DEMs closely approximate the existing streams and channels represented in the USGS DLG data sets in areas of high or medium relief. Additionally they are good for delineating the full channel network, including intermittent streams and hollows, which we also need to measure to calculate watershed morphometric parameters such as stream density.

The lower the flow accumulation threshold we use, the further up into the headwaters we are able to delineate drainage patterns. Once we display all the flow accumulation values starting with the value of 1 we have shaded the entire area with the exception of zero flow accumulation cells which approximate the location of ridge crests. To create a single value grid (with background of NODATA) that represents streams we use the **RECLASS** function to reclassify the flow accumulation grid. To reclassify we first have to create a remap table. The simplest form of a remap table is an ascii file made in the text editor that contains following information:

30 53460 : 1

<space>

The value 30 is the lowest value that will be reclassified, while the value of 53460 is the highest value. The highest value to be reclassified is in this case usually the highest value in the flow accumulation grid, which we can find out using the **DESCRIBE** command. The syntax of the **RECLASS** function is as follows:

streams = reclass (flowcount, remappable)



In that way we can delineate drainage networks up to their upper reaches.

NOTE:

The flow accumulation map is very useful in helping us locate watershed outlet points. In a flow accumulation map a cell with a value of 10 can be located very near a cell with a flow accumulation of 20000, except that it is not on the flow path. Visually locating outlet points might be inaccurate enough to result in placing the location for the outlet on the cell with a value of 10, which means that the watershed program will delineate for it a basin consisting of the 9 cells that flow into that particular cell, a very small area indeed. ARC GRID contains a **SNAPPOUR** function which corrects that problem by moving the location of the selection to the nearest cell within a user specified radius that has the highest flow accumulation value, and is therefore more likely to be located on a major drainage.





outlets = snappour (<*>, flowcount, 100)

or

outlets = snappour (seedsgrid, flowcount, 100)

or

outlets = snappour (seedscover, flowcount, 100)

In the first case we are creating a corrected outlets map with the screen cursor, in the second case with a grid of outlets or watersheds seeds, and in the third case from a vector point file.



3.2. Identify stream juncture locations and convert modeled stream networks into line data

We have now modeled a stream and channel network for our study area. To model watersheds for these streams and then order the streams according to a morphometric ordering scheme we need to find the points where various stream reaches meet, i.e., stream junctions. We can do this as follows:



streamlinks = streamlink (streams)



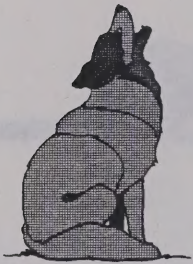
The streamlink function assigns unique values to the reaches of a linear network of streams in grid cell format. The reaches, here referred to as links, are the portion of stream between successive junctions, or intersections between streams.

Identifying unique reaches of streams is important both for ordering of streams and for a more accurate vectorization into line data than can be obtained using the streamline function.

streamlines = streamline (streamlinks, flodirfilld)



Streamline is a vectorization program to be used specifically with linear network data, such as stream data. It's performance is improved over the gridline function by use of the flow direction grid to aid in vectorizing adjacent cells that represent intersection points. This permits two adjacent linear features with the same value to be vectorized as two parallel lines rather than one line, as would happen with gridline. This capability is very useful when dealing with streams that flow into each other but continue for a while on a close parallel course.

**NOTE:**

Although the streamline function will vectorize the raw linear network such as we get by simply reclassifying the flow accumulation map into a streams map, it works better if the network file used is a product of a streamlink function. Using a streamlink map it is easier for streamline to assign unique values to arcs and vertices of the new vector network coverage.

Exercise 3. Delineate and order drainage networks and create watersheds based on stream junctions.



A. Delineate and order drainage networks

In 1940's and 1950's there was an explosion of interest and research in geomorphometry, or the science and methods of measurement of earth features which is a branch of geomorphology. Although researchers realized that various processes can result in similar forms, analysis of landform shape still became a major tool for all geomorphologic research because it can still tell us a lot about the processes that shape the landscape.

Because of orientation toward the study of hydrologic and related geomorphic processes, drainage networks and watersheds were a natural focus for research by scientists from various disciplines. Some of the greatest contribution to watershed, drainage network and hillslope geomorphology were made by a hydrologist R. E. Horton, who proposed the Horton cycle of precipitation and runoff which included the concept of overland flow, and a method for ordering streams.

Stream ordering forms an important part of geomorphometric analysis of stream networks. ARC/INFO GRID provides algorithms for two types of ordering schemes. The first one devel-

oped by Strahler in 1952 and an improvement on Horton's work permits increase in stream order only if streams of the same order intersect. For example, two upland streams without any tributaries join together to form a larger stream. Both are order 1 streams and form an order 2 stream. On the other hand, if another order 1 stream joins the fully formed order 2 stream, the stream remains order 2 until it joins another order 2.

This is not the case in the second stream ordering system available in GRID based on approach proposed by Shreve in 1967. Here each new junction of streams results in a higher order. When two order 1 streams meet they form an order 2 stream, but when another order 1 stream joins the new order 2 stream, the new stream is assigned an order of 3. The Shreve system of ordering streams has the benefit of assigning a higher order each time flow increases due to addition of another tributary, so that we have a better sense the accumulation of runoff throughout the landscape. With the availability of flow accumulation maps, however, one wonders whether it might be possible to develop an ordering approach which takes the more precise flow accumulation together with stream segments to form a more accurate index for stream order. In the following example we will use the more traditional Strahler ordering system.



strmordstrah = streamorder (streamlinks, flodirfilld, ~strahler)

The product of this command is a grid which has stream order value assigned to each stream segment or link according to Strahler's stream ordering system. However, we would like to also be able to delineate basins the outlet points of which are the junctions between stream channels. In that way we will obtain a map of watersheds to which we can assign an order number related to the stream section they supply, and dependent on the ordering system we use.

B. Create watersheds based on stream junctions.

One approach to creating an outlet map used for seeding watersheds at stream outlets is based on using the original streams map we created by selecting cells from the flow accumulation grid. In the last section prior to this exercises we created a line coverage of streams using the **STREAMLINE** and **STREAMLINK** functions. We would now like to be able to delineate a watershed for each link (segment, reach) of the drainage network. To create such a map we need to find the watershed for each of the nodes an arc that represents a stream is pointing towards, which essentially includes all the intersection points or junctions in our vector stream map. To extract all the nodes and turn them into points we should use the **NODEPOINT** command in ARC.



ARC: NODEPOINT STREAMLINES JUNCTIONS

ARC: BUILD JUNCTIONS

The second ARC command, **BUILD**, builds a point attribute table for the JUNCTIONS map. To make the JUNCTIONS map into a watershed outlet map now need to convert the point map into GRID format as follows:



outlets = pointgrid (junctions)

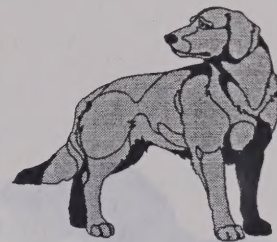
We now have a grid map of watershed outlets at the locations of junctions between stream segments. Since our original map was created from a flow accumulation map, we do not have to worry about moving outlet points to nearest locations with high flow accumulation using the SNAPPOUR function. The points are already located on the areas of highest flow concentration. Therefore the next step is to simply generate the watersheds.



junctsheds = watershed (flowdirfilld, outlets)

Retrieve on-line help information on related topics:

- in ARC type "HELP"
- when Table of Contents appears while holding down the right mouse key select GRID functions
- select, print, and read descriptions of the FLOWACCUMULATION, RECLASS, SNAPPOUR, STREAMLINK, and STREAMLINE functions



4. *Delineate watersheds automatically using flow increase thresholds*

4.1. Identify flow increments



A flow increment value is the increase in flow from one cell to another cell on a flowpath. It is obtained by subtracting from the flow accumulation value of the current cell the value of the previous cell on the flowpath. This measures how much increase in flow there is along the flowpath. Generally if there is no tributary entering the stream the increase in flow accumulation along a flowpath, which for convenience we shall call the *delta value*, is equal to 1. However, at a junction of streams flow accumulation value will suddenly increase by the amount contributed by the tributary.

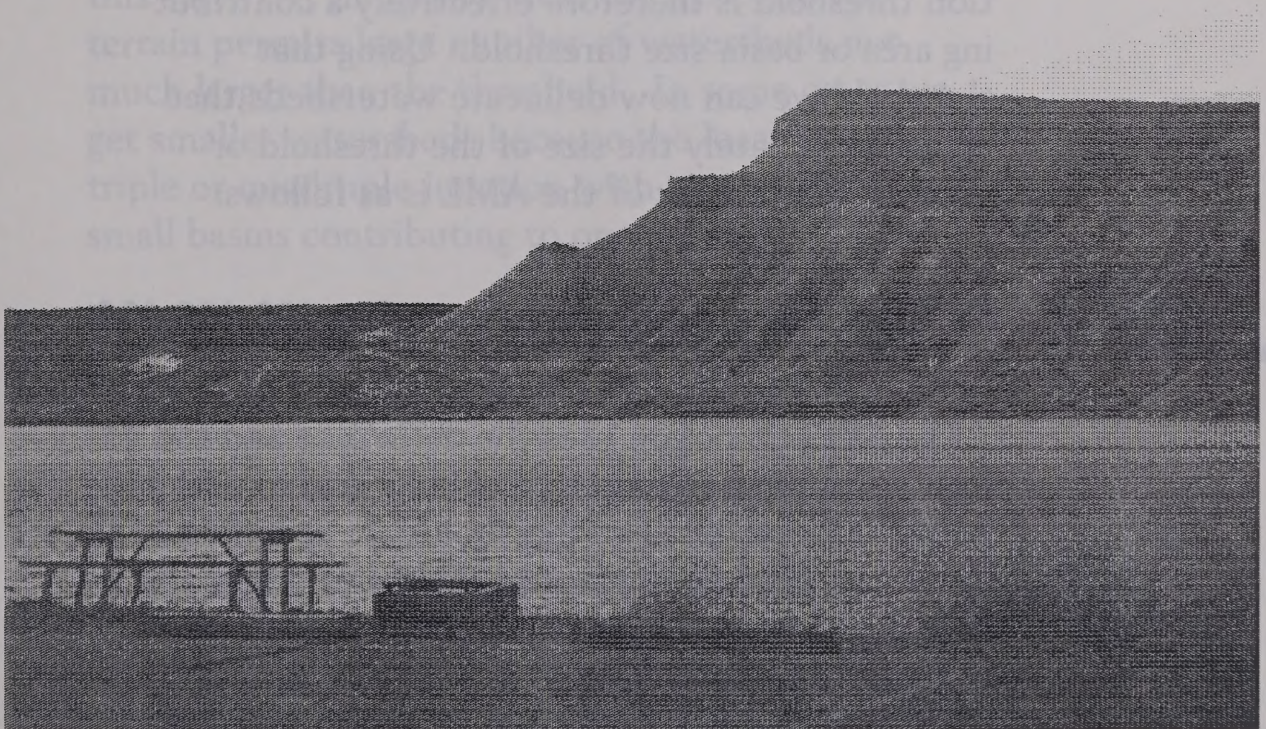
ARC GRID does not provide a way to measure flow accumulation increase from cell to cell, but our friends at the USGS, following Sue Jenson's original strategy, developed AMLs which perform this function and which they have kindly provided for us. The AMLs are called from the GRID module to perform two very important

functions. The first AML calculates flow increases from cell to cell on a flowpath across the entire grid as described above.

&r delta flowdirfilld flowcount deltagrid



The delta, or flow accumulation increase, map can now be used to automatically find watershed outlet points for watersheds not smaller than a user specified threshold, which will be discussed in the next section. One can easily imagine, however, that a flow increase map could, for example, be potentially useful for identifying locations



prone to flooding.

4.2. Find watersheds outlets using a flow increase threshold and grow watersheds from the outlet point map.

Once the deltaflow map has been created, the second AML we obtained from the USGS, called **SEED.AML**, is now able to find watershed outlet locations using a flow increase threshold. A flow increase threshold is essentially an area related variable, because what it really means is that flow accumulation was increased by contribution of flow from a certain area equal in size to the flow increase. A flow accumulation increase of 100 means that 100 cells, each .224 acres in area, have contributed to the increase. The flow accumulation threshold is therefore effectively a contributing area or basin size threshold. Using that threshold we can now delineate watersheds that are approximately the size of the threshold or greater. The syntax of the AML is as follows:



```
&r seed deltagrid flowcount outlets100 100 100
```

The SEED function uses the delta map and the flow accumulation map to create a grid of outlet points outlets100. The thresholds are specified as the last two numbers on the command line: the first threshold is the delta threshold which refers to increase in flow, and the second threshold is the flow accumulation threshold, which refers to the flow accumulation level we do not want to get below. The second threshold is useful only if we

want to delineate stream junctions for flows over some flow accumulation value. Then, using our seed map as an outlet point map we apply the watershed function.

sheds100 = watershed (flodirfilld, outlets100)



If we now use the **ZONALAREA** function to calculate the area of each miniwatershed we will discover that the areas are generally not smaller or much larger than the area limit indicated by the flow increase threshold. The seed function identifies all the points where there is a flow increase greater than the threshold value that occur at stream junctions. Unless we get into areas where the number of junctions decreases drastically, such as very flat areas which can't be modeled well with this software, in upland areas the dissection of terrain permits large number of watersheds not much larger than the threshold. In some cases we get smaller watersheds because the location is a triple or quadruple junction with several distinct small basins contributing to one point.

For quick calculation of the area of mini-basins you just derived using the watershed function, use the zonalarea function.

sheds100area = zonalarea (sheds100)



This command will provide you with a map that contains values for each watershed that represent the area of the watershed in units of the map, usually square meters. To obtain the values in acres divide the sheds100area maps by 4046.856 meters per acre. By applying different flow increase thresholds you can obtain larger or smaller mini-basins to aid with your analysis of the terrain.

Exercise 4. Delineate watersheds mostly over 4000 acres in size and then subdivide them into mostly larger than 200-acre mini-basins.



The unhandy way of expressing the concept of flow increase thresholds and their relationship to area measurements arises from the fact that we cannot expect the terrain to be nicely subdivided into natural units with equal areas. In that sense the watersheds are a class of abstraction which brings together the unique ability of terrain morphology to gather rainfall toward a single outlet as the identifying feature of the class. Watersheds of different sizes possess the same characteristic which makes them a useful interscale systems analysis tool. Therefore we cannot really talk about 200 acre or 4000 acre watersheds without meaning this as a purely approximate identifier based on the flow increase map.

To estimate boundaries of approximately 4000 acre or larger watersheds we first need to calculate the number of 30 m x 30 m cells it takes to make up 4000 acres, assuming that 900 square meters are equal to about .224 acre. $4000/.224 = 17857$ that can be rounded off to 18000. We therefore use the seed command:



&r seed deltagrid flowcount outl4000A 18000 100

We make the same calculation for 200 acre watersheds. $200/.224 = 893$ cells which we can round off to 890 cells.

When we display these maps on the screen or plot them on the plotter using different colors to mark different flow increase threshold levels we will see that the mini-watershed boundaries fit precisely within the watershed boundaries.

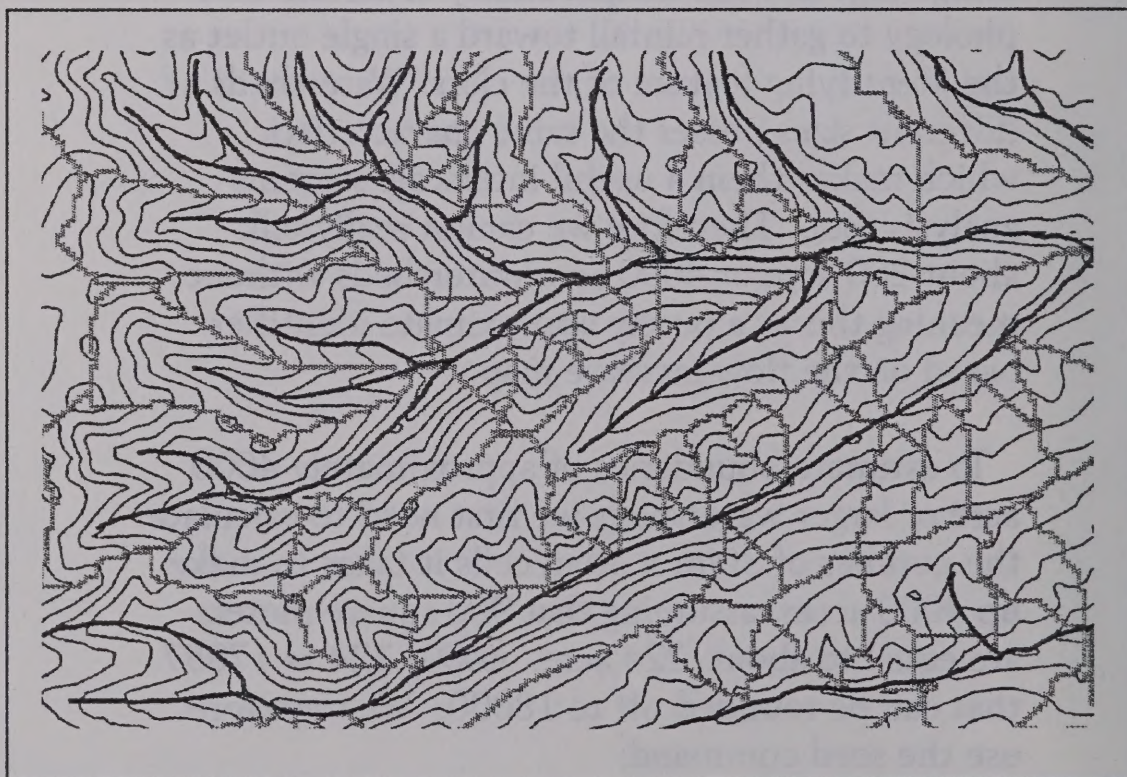


Figure 5. Watersheds derived for a outlet points created automatically with the SEED and DELTA functions applied to a filled DEM, streams obtained from the USGS DLG data sets, and 20 m contour lines for a portion of the Sagebrush Hill USGS 7.5 minute quadrangle.

5. Beyond watershed delineation: future capabilities.

Once we are able to delineate watersheds of various sizes at will both for objects placed in the terrain and for manual or automatically input outlet points, we can begin to use the watershed or the mini-watershed as an analytic unit. How that can be done is currently in the works.

Stream ordering is only one aspect of geomorphometry. Our busy friends at the USGS have been working on developing a system for morphometric analysis of basin parameters, such as relief ratio or drainage density. Being able to obtain quantitative variables that describe the basin permits us to also describe the terrain morphology of the area and distribution of surface waters which both relate to the functioning of local ecosystems. In fact, the only reason more work has not been done on correlating watershed morphometry with other ecosystem variables is because they were so hard to measure. Advent of easily available printed topographic maps in the early twentieth century resulted in a boom in geomorphometry based on analysis of contour lines to derive watershed boundaries, slope gradients, slope lengths, and other variables.

Perhaps GIS and DEM data can bring another such boom by permitting us to analyze correlation between terrain morphology and other ecosystem variables.

Some examples of watershed morphometric parameters which we should be able to derive using GIS in the near future include:

1. average basin slope, in feet per mile, measure by the "contour-band" method, within the contributing drainage area;
2. shape factor, dimension less, ratio of basin length to effective basin width;
3. elongation ratio, dimension less, ratio of (1) the diameter of a circle equal to that of the basin to (2) the length of the basin;
4. rotundity of basin, dimension less;
5. compactness ratio, dimension less, the ratio of the perimeter of the basin to the circumference of a circle of equal area;
6. relative relief, in feet per mile, the ratio of basin relief to basin perimeter;
7. main channel slope, in feet per mile, an index of the slope of the main channel computed from the difference in streambed elevation at points 10 percent and 85 percent of the distances along the main channel from the basin outlet to the divide;
8. main channel sinuosity ratio, dimension less, the ratio of main channel slope and basin length;
9. stream density in miles per square mile;
10. constant of channel maintenance in square miles, or the area needed to maintain a mile of channels, and an inverse of stream density;
11. main channel slope proportion, dimension less,
12. ruggedness number, in feet per mile, a product of stream density and basin relief;

and more.

Appendix A:
BLM Information Bulletin No.
RS-96-020:

INTERIM GUIDANCE
Standard Watershed and
Subwatershed Boundaries,
Codes, and Automated Base
Maps.

In recent years, land management and other government agencies have recognized the need to subdivide the current NRCs into smaller watershed areas and to create digital map files of the boundaries for these units. Such work has been completed or is going on all over the country. At the federal level, the Natural Resources Conservation Service (NRCS) developed a working draft National Instruction No. 170304, Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit Boundaries, and distributed it as guidance to their field offices.

Also, the NRCS distributed the working draft to other federal agencies for review. In response, the BLM and the US Forest Service jointly reviewed the working draft and transmitted comments to Paul W. Johnson, Chief, Natural Resources Conservation Service. A copy of BLM and FS comments are attached for your use. The NRCS working draft, as revised by the BLM and FS comments is the preferred method for subdividing and digitizing NRCs in our agency.

Perhaps GIS and DEM data can bring another
level of evidence to an analysis by showing
relationships between terrain morphology and other
variables.

Appendix A:

BLM Information Bulletin No. 90-020
This is a brief, one-page summary
of the information contained in the
bulletin.

1. The purpose of this bulletin is to provide
information on the use of GIS and DEM data
in the analysis of terrain morphology.

2. The purpose of this bulletin is to provide
information on the use of GIS and DEM data
in the analysis of terrain morphology.

3. The purpose of this bulletin is to provide
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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
NATIONAL APPLIED RESOURCE SCIENCES CENTER
P.O. BOX 25047
DENVER, COLORADO 80225

JUL 2 1986

Office Code	Surname	Date
RS-130	Smiller	
RS-100	LBarkow	
RS-130	EPacheco	

In Reply Refer To:
7210 (RS-130)

Information Bulletin No. RS-96-020

To: All State Directors

From: Director, National Applied Resource Sciences Center

Subject: INTERIM GUIDANCE Standard Watershed and Subwatershed
Boundaries, Codes, and Automated Base Maps

This is to inform you about the status of interagency efforts to develop national guidelines for subdividing and digitizing the Hydrologic Units of the United States. The Hydrologic Unit Codes and Names (HUCs) are a Federal Information Processing Standard (FIPS) that was developed through an intergovernmental consensus process in the late 1970s and early 1980s. The smallest Hydrologic Units (the 8-digit Cataloging Units) in the FIPS are about 700 square miles, and some are well over 10,000 square miles.

In recent years, land management and other government agencies have recognized the need to subdivide the current HUCs into smaller watershed areas and to create digital map files of the boundaries for these units. Such work has been completed or is going on all over the country. At the federal level, the Natural Resources Conservation Service (NRCS) developed a working draft National Instruction No. 170304, Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit Boundaries, and distributed it as guidance to their field offices.

Also, the NRCS distributed its working draft to other federal agencies for review. In response, the BLM and the US Forest Service jointly reviewed the working draft and transmitted comments to Paul W. Johnson, Chief, Natural Resources Conservation Service. A copy of BLM and FS comments are attached for your use. The NRCS working draft, as revised by the BLM and FS comments is the preferred method for subdividing and digitizing HUCs in our agency.

COPY FOR YOUR
INFORMATION

Recently, the BLM, FS, and NRCS have requested that the Subcommittee on Spatial Water Data coordinate a high-priority interagency process to adopt consensus national guidelines using the NRCS National Instruction and our comments as the starting points. The Subcommittee is jointly sponsored by the intergovernmental Water Information Coordination Program and the Federal Geographic Data Committee. As an overall goal, the agencies intend to develop national guidelines that will ultimately result in consistent spatial data map files for watersheds and subwatersheds. Over time, consistent local regional, and national spatial data coverage for watersheds will be created.

In the interim, watershed delineation work that is already completed should not be changed immediately. However, please use these preferred procedures in the future when you are making routine changes to your watershed files, when you initiate watershed delineation in the future, when you coordinate watershed mapping or digitizing efforts with other agencies, and when other such opportunities arise.

If you need further information, please contact Ervin Cowley, Idaho State Office, at (208) 384-3054 or Dan Muller at (303) 236-7198.

2 Attachments

- 1 - BLM/FS Comments/Letter to NRCS (5 pp)
- 2 - Working Draft - National Instruction No. 170-304 (38 pp)

Distribution

WO-400, MIB, RM 5656
 RS-150, BLM Library
 DW-101, Reading File
 Ervin Cowley, ID-913
 Nancy Lopez, WO-480

RS130:DMuller:ep:7/02/96:J:\210share\swa\Hydrcode.dm



U.S. Department of the Interior
Bureau of Land Management
Washington, D.C. 20240



U.S. Department of Agriculture
Forest Service
Washington, D.C. 20090

File Code: 2500/7200

Date: 8 MAR 1990

Paul Johnson, Chief
Natural Resources Conservation Service
U.S. Department of Agriculture
Washington, D.C. 20250

Dear Mr. Johnson:

The purpose of this joint letter is to support the need for common guidelines and criteria for delineating and digitizing watersheds and subwatersheds of the hydrologic units (HU's) of the United States. On behalf of the Forest Service (FS) and the Bureau of the Land Management (BLM), we want to express our appreciation for the significant contributions of the Natural Resources Conservation Service (NRCS) in leading this important interagency effort.

Interagency aspects of the HU's delineation initiative are conducted through the Subcommittee on Spatial Water Data that is jointly sponsored by the Federal Geographic Data Committee and the Water Information Coordination Program. The development and adoption of common guidance and criteria for delineating watersheds is part of the Administration's initiative to establish the National Spatial Data Infrastructure.

On May 25, 1995, technical staff from the FS and BLM met with representatives of the NRCS, the U.S. Environmental Protection Agency, and the U.S. Geological Survey to discuss the status of watershed delineation activities within the agencies. At that meeting, Roger Cronshey, NRCS, provided copies of the working draft (revision date April 19, 1995) of the NRCS National Instruction No. 170304 (Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit Boundaries). Our staffs have reviewed the National Instruction, and we believe it is a good starting point for developing common guidelines for use by all levels of Government and the private sector.

As a result of our review, we have identified certain revisions that are needed to allow use of the National Instruction in the FS, BLM, and other organizations. Our comments are provided in the enclosure.

Attachment 1

Paul Johnson, Chief

Delineating watersheds and subwatersheds within the existing HU structure is one of the steps needed to achieve comprehensive watershed management throughout the Nation. Given the current funding and staffing constraints, wide adoption and use of common guidelines and criteria for delineating such areas is the best approach for ultimately achieving common watershed designations. The FS and BLM will actively participate with the NRCS and other agencies to develop and implement the delineation guidance.

Sincerely,

Mat Millenbach

for MIKE DOMBECK
Director
Bureau of Land Management

for JACK WARD THOMAS
Chief
Forest Service

cc: Frank Ward Thomas, Chief FS
Warren Harper, Water Resources Program Manager, FS
Gale TeSelle, NRCS
Tim Smith, Chair, Subcommittee on Spatial Water
Data, USGS
Mike Domaratz, Executive Secretary, FGDC

National Instruction No. 170-304: Mapping and Digitizing
Watershed and Subwatershed Hydrologic Unit (HU) Boundaries

The Forest Service (FS) and Bureau of Land Management (BLM) have reviewed the draft National Instruction dated April 19, 1995, and we support most of the criteria documented in the draft National Instruction. Our comments and suggested revisions to the draft are presented below:

MAJOR COMMENTS AND SUGGESTED REVISIONS

1. General: The draft National Instruction proposes a 3-digit field length for the 5th and 6th fields to be added to the standard HU codes. According to the draft guidance, the purpose of the third digit proposed by NRCS is to allow future changes in delineating HU's. We have concluded that it is important to maintain the 2-digit field length for successive 5th, 6th, and any future fields defining higher resolution subdivisions within the current nested coding scheme. The use of a 2-digit field length is consistent with the pattern established by the interagency committee and described in the nationally accepted delineation of HU's published on behalf of the committee by the U.S. Geological Survey (USGS) (Seaber, et al., 1987). Also, the nested 2-digit coding system is a Federal Information Processing Standard (FIPS). Changing field lengths in the code defeats the purpose of the FIPS. The HU's are an integral part of environmental information systems throughout the public and private sectors. Changing to a 3-digit field will cause wide-spread confusion and wasted resources.

2. General: The nested coding system using successive 2-digit fields does allow for future subdivisions. The FS and BLM have tested the adequacy of the 2-digit field standard in several large western states. Mapping in the Columbia River Basin and other major drainage in Oregon, Idaho, and California has shown that a 2-digit field length is adequate to handle nested delineations over a very wide range of topographic and hydrologic conditions. The nested hierarchy adopted in the FIPS provides for structured subdivision of 5th field watersheds and smaller delineations.

3. General: The National Instruction proposes size as the criteria to determine subdivisions: 40,000 to 250,000 acres for watersheds (5th field) and 10,000 to 40,000 acres for subwatersheds (6th field). This approach does not accommodate geomorphic or other relevant basin characteristics. Different areas of the country have different needs. For example, the size area that works on the Great Plains could not be expected to work in the Northeast. As a general rule, we suggest that each HU within a level of delineation be subdivided into 5 to 15 units. That is, 5 to 15 watersheds (5th field) would be nested in each cataloging unit (4th field) and 5 to 15 subwatersheds (6th field) would be nested within each watershed.

4. Page 14, Unconsolidated Areas: Instead of naming these areas "unconsolidated," we suggest calling them "Related Contributing Drainage Areas." Also, we suggest the following definition for such areas: "Areas that do not have a single drainage point, but that contribute to the same larger waterbody." These areas typically show up as wedge shaped areas between adjacent drainage basins that have well defined outlets. Examples of contributing areas are frontal and interfluvial areas along large

ivers, areas with several similar individual streams entering the same larger waterbody (e.g., lakes, ocean) or several islands grouped together. If such areas are of sufficient size they should be mapped as separate HU's. If such drainage areas contribute relatively small flow volumes, they should be delineated in an adjacent HU with similar characteristics.

5. Page 14, Noncontributing Areas: Areas that do not flow toward an outlet or stream (e.g., a closed basin). Typically, such areas include glaciated plains (potholes), karst topography, playas, depression lakes, or other similar land forms.

6. Page 14, Diverted Waters: The BLM and the FS agree with the concept of using database attributes to link HU's that are associated through a continuous diversion of water by constructed diversions. The wording in this paragraph and the example provided in Figure 2 may lead users to conclude that areas above diversions are to be mapped and physically associated with the receiving hydrologic unit. Obviously, this is not practical in situations where the receiving HU is not adjacent to the source HU. Also, in some cases only part of the flow is diverted. The first sentence should be reworded to clarify these points. The sentence would then read: "When all or part of the flow from one HU is continuously discharged into another by constructed transbasin diversions, the diverted flow should be documented as an attribute of the water losing HU and as an attribute of the gaining HU...."

7. Page 15, number (8) Ditches: The BLM and the FS do not agree that small ditches should be treated as streams. Instead, we recommend ignoring small constructed ditches in the delineation of stream networks within any given HU. It is a common practice to move ditches through reconstruction or the use of a pipeline. Using natural hydrologic features to define watersheds is preferable to delineating small ditched areas. Consistent with the discussion in comment 6 above, constructed changes to natural drainage systems need to be documented in attributes.

8. Page 28, Hydrologic Unit: The wording in the definition of Hydrologic Unit should be modified to make the attribute association clear by removing the words "...to form a landform..."

9. Page 3: The FS and the BLM support the use of the terms basin, subbasin, watershed, and subwatershed as labels for the 3rd, 4th, 5th, and 6th field hierarchical levels. Also, we support two additional subdivisions within the subwatershed as follows: "drainage area" (7th field) and "project area" (8th field). This would provide consistent delineation to the smallest HU needed for project planning.

Drainage area (7th field): Typically would be nested inside the 6th field HU. The size would generally be 3,000 to 10,000 acres. All guidelines contained in this document would apply to these HU's

Project area (8th field): The smallest HU used for project planning. This size would be nested inside a drainage area HU. The size usually would be less than 3,000 acres.

10. Page 5: What National group will be responsible for archiving, maintaining, and distributing HU databases? Since the HU's are part of the National Spatial Data Infrastructure, we anticipate that the Federal Geographic Data Committee (FGDC) will resolve this question.

11. Page 7, Section 304.10(a): Mentioning the interagency coordination that exists at the national level FGDC, Water Information Coordination Program, and others in section 304.10(a) seems appropriate.

12. Page 10, Section 304.20: The FS and the BLM have found that preparing a GIS plot for each 4th field HU along with 1:100,000 hydrography and associated 1:24,000 USGS quadrangle corners on a single page helps to locate 5th field watersheds. These plots allow a quick orientation and greatly ease the task of identifying which 1:24,000 USGS quadrangles are needed for the final delineation of the watersheds.

13. Page 29: Consistent with the above revisions and to avoid confusion, remove the recommendation that States (and others) using 10-digit HU codes convert to 11 character codes, and those using 13 digits convert to 14 character codes.

USDA Natural Resources Conservation Service
National Resources Inventory Division
P.O. Box 1396
Washington, D.C. 20013

NATIONAL INSTRUCTION NO. 170-304

MAPPING AND DIGITIZING WATERSHED AND SUBWATERSHED HYDROLOGIC UNIT BOUNDARIES

USDA Natural Resources Conservation Service
Natural Resources Inventory Division
P.O. Box 2890
Washington, D.C. 20013

Preface

This agency instruction for standardizing the mapping and digitizing of Watershed and Subwatershed hydrologic unit boundaries was first issued in July 1992. The Natural Resources Conservation Service (NRCS) has continued to work with other federal and state agencies and with the Water subcommittee of the Federal Geographic Data Committee to establish a Federal standard covering mapping and delineation of hydrologic unit boundaries. This June 1995 issuance incorporates changes based on review outside our agency, revised roles and responsibilities within NRCS due to reorganization, and specifies that all digitization be based on hydrologically defined boundaries delineated on 1:24,000 scale base maps. As a result this Instruction is called a working draft.

Comments and or questions regarding this working draft should be directed to Roger Cronshey of the Natural Resources Inventory Division at the address indicated on the cover page. Other communication media that can be used to contact Roger include:

Phone (202) 720-4821

Voicecom 720-4821

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E-mail rcronshey@nhq.nrcs.usda.gov

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SUB PART A - INTRODUCTION

304.00 Purpose.

This instruction establishes guidelines for mapping, describing, and digitizing Watersheds and Subwatersheds at a 1:24,000 scale. These hydrologic unit (HU) boundaries define the locations of the 11 digit HU (Watershed) and the 14-digit (Subwatershed).

304.01 Background.

A nationally uniform HU system was developed in the mid 1970's by the US Geological Survey (USGS), Office of Water Data Coordination (OWDC) under the sponsorship of the Water Resources Council (WRC). This system divides the country into 21 Regions, 222 Subregions, 352 Accounting Units, and 2,149 Cataloging units based on surface hydrologic features. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area of interest. NRCS refers to the Accounting Unit (6 digit) drainage as a "Basin" and the Cataloging Unit (8 digit) as a "Subbasin". The smallest Subbasin is approximately 448,000 acres (700 sq. miles).

In 1978, Soil Conservation Service (SCS) issued a policy that all resource inventories and surveys were to be coded with and capable of being retrieved by HUCs. At about the same time, SCS initiated a national program to further subdivide HUCs into watersheds for use in water resource planning. An extension of 3-digits was added to the 8-digit HUC to designate a "Watershed". An 11-digit Watershed HU is typically 40,000 to 250,000 acres in size. By 1982, SCS completed mapping the Watershed boundaries in nearly all states using 11-digit identification codes.

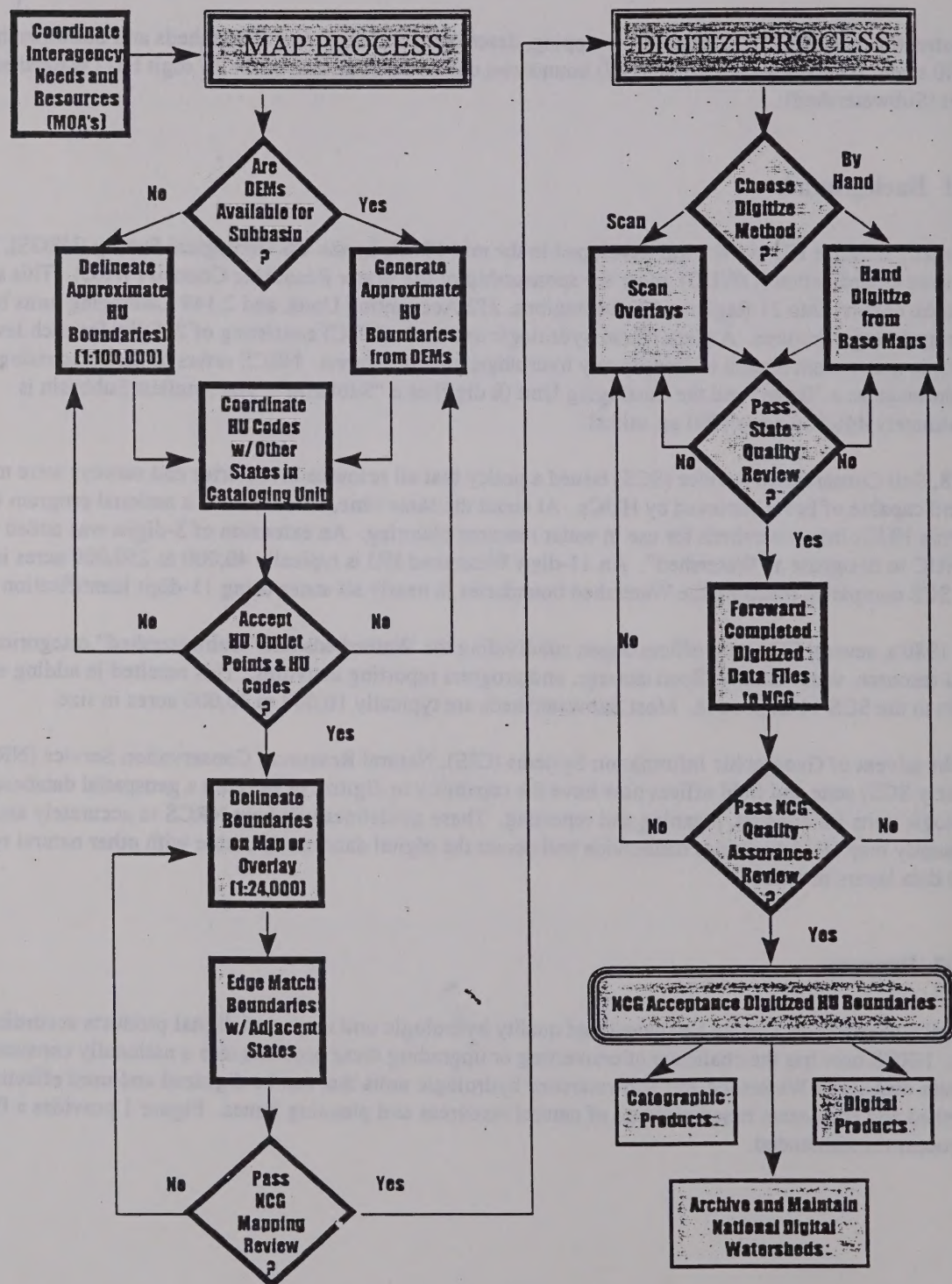
In the 1980's, several SCS state offices began subdividing the Watersheds into "Subwatershed" categories for use in natural resource, water quality, flood damage, and progress reporting activities. This resulted in adding either 2 or 3-digits to the SCS 11-digit code. Most Subwatersheds are typically 10,000 to 40,000 acres in size.

With the advent of Geographic Information Systems (GIS), Natural Resources Conservation Service (NRCS) (formerly SCS) state and field offices now have the capability to digitize or develop a geospatial database of hydrologic units for analysis, planning and reporting. These guidelines will help NRCS to accurately and consistently map HU boundaries nationwide and assure the digital database is usable with other natural resource digital data layers in a GIS.

304.02 Process

The Soil Conservation Service had developed quality hydrologic unit maps and digital products according to state needs. NRCS now has the challenge of converting or upgrading these products into a nationally consistent and seamless data set of Watershed and Subwatershed hydrologic units that can be digitized and used effectively in watershed and ecosystem based analyses of natural resources and planning issues. Figure 1 provides a flow chart of the process recommended.

Fig. 1 - Watershed and Subwatershed Development Process



304.03 Responsibility.

(a) Natural Resources Inventory Division (NRI).

The NRI Division is responsible for the program management of the Watershed and Subwatershed hydrologic unit mapping and digitizing activity. This includes development and maintenance of the guidelines for mapping and digitizing the HU boundaries to complete a nationally consistent and seamless data set. NRI also will coordinate progress reporting, training, funding, scheduling, and interagency coordination.

(b) State Conservationist.

The state conservationist has overall responsibility for the mapping, data description, and digitizing of hydrologic units. These responsibilities include: implementing the mapping and digitizing guidelines; matching HU boundaries with adjoining states; coordinating with other agencies; and maintaining quality control to assure accuracy and completeness of the data.

(c) Regional Conservationist (RC).

The primary role of the RC is to ensure that the national hydrologic unit map compilation is developed according to NRCS standards (NI 170-304). The RC's provide assistance to states in the mapping and digitizing of HU's. The RC is responsible for the final review of mapping and compilation prior to digitizing. RC's will provide training and direct assistance to state offices to coordinate the matching of hydrologic unit boundaries and database attributes across state boundaries and maintain a consistent level of mapping detail.

(d) National Cartography and Geospatial Center (NCG).

The National Cartography and Geospatial Center (NCG) is responsible for quality assurance of boundary delineation concerning mapping and digitizing standards, as well as, archiving, maintaining, and distributing the HU geospatial database. NCG certifies all digitizing of HU's and integrates state digital layers into the national digital data layer for Watersheds. NCG also participates in training.

304.04 Application and Uses of Hydrologic Units.

Below are some applications of Watershed and Subwatershed HU's:

- Assess on site and off site effects of resource management systems.
- Coordinate conservation planning across political boundaries.
- Evaluate conservation planning alternatives.
- Flood damage assessments.
- Identify water quality problems such as point and non-point sources.
- Overlay to other geospatial databases and perform GIS spatial analysis.
- Program management and evaluation.
- Progress reporting.
- Resource inventory data collection.
- River basin planning.
- Water Quality Planning.

- Water use reporting.
- Watershed planning and protection.
- Ecosystem based assistance.
- Wetlands inventory.

SUB PART B - COORDINATION

304.10 Interagency Coordination.

(a) General.

The delineation of 11 and 14 digit hydrologic units is an opportunity to develop a consistent and common statewide database for interagency sharing of geospatial and attribute data, as well as improving federal, state, and local interagency relations.

Interagency coordination provides the following benefits:

- 1) Improves interagency agreement as to the need to delineate HU's and to define their uses and applications.
- 2) Sets forth an agreement to establish procedures, standards, guidelines, quality control, coordination and management of a hydrologic unit mapping project.
- 3) Promotes geospatial and attribute database sharing between agencies.
- 4) Provides opportunity to obtain financial support, in-kind services and cost sharing.

(b) Costs.

About eighty percent of all development costs for GIS is in data collection and digitization. For this reason, it is essential that data be recorded on an accurate geo-referenced base map such as the USGS quad maps. Wherever possible 1:24,000 scale quad sheets should be used. It is important that agencies agree to use a common set of guidelines. This keeps the data consistent, accurate and allows for data sharing without having to duplicate efforts.

(c) Interagency Coordination Process.

- 1) Contact potential state and federal agencies interested in establishing statewide consistent HU's. State and federal agencies interested in using hydrologic unit maps and digital data may include:

State Agencies

- Agriculture
- Conservation
- Emergency Planning
- Environmental
- Fisheries
- Forestry
- Geologic Survey
- GIS (lead agency)
- Natural Resources.
- Planning.
- Pollution control.
- Transportation or highway.

- Water resources.
- Wildlife.

Federal Agencies

- Bonneville Power Administration
 - Bureau of Indian Affairs.
 - Bureau of Land Management.
 - Bureau of Reclamation.
 - Consolidated Farm Services Agency
 - Corps of Engineers.
 - Department of Defense.
 - Environmental Protection Agency.
 - Federal Emergency Management Agency.
 - Forest Service.
 - National Biological Survey
 - National Oceanic & Atmospheric Administration (NOAA)
 - National Oceanographic Service
 - National Park Service.
 - National Weather Service.
 - Natural Resources Conservation Service.
 - Tennessee Valley Authority
 - US Fish and Wildlife Service
 - US Geological Survey, Water Resources Division
- 2) Conduct a HU meeting to discuss level of interest, uses, needs, and potential participation. Determine responsibility for coordinating and chairing the meeting.
 - 3) Consider developing a multi-agency Memorandum of Understanding (MOU) for those interested in participating in a hydrologic unit mapping project of the state.

(d) Memorandum of Understanding (MOU).

Some items to consider including in an MOU are listed below. Guidelines for some of these are described in this document.

- 1). The map scale and maps that will be used to develop a statewide HU map.
- 2) Responsibilities for mapping and digitizing.
- 3) Responsibilities for managing and coordinating the mapping and digitizing. Coordinate boundaries and HU coding with adjoining states.
- 4) Estimate of time to do the mapping and digitizing.
- 5) Estimate of time to supervise the project and training required for mapping and digitizing.
- 6) Mapping and digitizing equipment, source documents, and space needs.

- 7) Plan for reviewing the completed mapping.
- 8) Agreement on the standards, procedures, and guidelines for mapping and digitizing.
- 9) Definition of map and digital products.
- 10) Plans to share, store and distribute the geospatial and attribute digital data within the state.
- 11) Total cost estimate for the project.
- 12) Responsibility for updating and maintaining the geospatial database.
- 13) Sharing of costs of base maps, expertise, cartographic and digitizing resources.

SUB PART C - MAPPING HYDROLOGIC UNITS

This part describes the maps to be used, criteria for determining the HU boundary locations, mapping procedures, describing the hydrologic unit, and assignment of HUC's. Minor variations in these guidelines and procedures are acceptable depending on the availability of maps, expected use of the data collected, and if resultant map meets standards for the national data set. It is permissible to use materials and techniques not described in the guidelines if they produce maps of equal or better quality. Any variations should be submitted to NCG, who will review and coordinate with NHQ for final decision.

All drainages digitized as Watersheds or Subwatersheds are to be done on 1:24,000 scale maps. This will produce information that is preferable for several reasons:

- To support field level analyses through the agency's analysis and planning programs, models, and Field Office Computing System (FOCS);
- For HU data that are consistent with other agency data sets that will be in use at the field offices (soils, plants and climate for example);
- To integrate with orthophotography information;
- This is also the preferred mapping level and scale if the data will later be merged to form a seamless county data set; and
- The resultant hydrologic delineation will have superior accuracy.

304.20 Maps to be Used.

(a) Initial Planning Maps.

It is advisable to obtain 1:100,000 scale base maps to use for initial planning for the detailed delineation that is to be done on 1:24,000 scale maps. Roughly locate the Subregion (8-digit) boundaries and provide a first cut of Watershed (11 digit) boundaries. This scale map is not detailed enough for delineation of the Subwatershed (14 digit) boundaries and will not provide a uniform detailed boundary for the Watersheds on a national scale. Obtain the unfolded litho printed paper copies of the USGS quad maps at the 1:100,000 scale. Keep the maps in good working condition and do not fold. Store the maps in a flat map file.

Alternatively generate and print a Subregion (8-digit) plot overlaid with available hydrology information and 1:24,000 scale USGS quadrangle corners. This can be used as an initial planning map and an index map (which is described later).

(b) Base Quad Maps.

Obtain the necessary unfolded litho printed copies of the USGS quad maps at 1:24,000 scale. Most of these 7 1/2 minute quad maps are published at 1:24,000 (1" = 2,000'), but some are at the 1:25,000 scale (1" = 2083') or 1:20,000 (1" = 1667'). The base maps need to contain standard features such as contours, roads, and drainage

patterns. Although the paper maps, handled carefully are adequate for this work, the punch registered mylar USGS base maps offer a more stable map base and more accuracy. The additional cost and delay in obtaining them, however, may be offset by the possibility of multiple use for other analyses. If obtained, retain the mylar copy as a permanent record. Do not use "bluelines" or similar copies. Do not have mylar copies made from the paper copies as this will result in map scale error.

In the contiguous US and Hawaii use only the USGS 1:24,000 scale maps. The USGS 1:20,000 scale quad maps should be used for the Caribbean and the 1:63,360 scale for Alaska. Exceptions are for the few areas where the 1:24,000 and 1:25,000 scale maps are available.

(c) Index Map.

Prepare an index map or layout of the entire area to be mapped. The USGS 1:24,000 index maps will meet this need (AK and Caribbean use 15 minute). The index map shows the relative positions and names of the different maps used. The maps can be used to track progress in mapping, joining, and digitizing and provide a good permanent record of the project.

(d) Reference Maps.

Other reference maps may be needed to determine and locate the hydrologic boundaries. These may include (but not limited to) the following:

- County drainage map;
- Direction of flow drainage maps;
- Ditch map;
- Storm sewer map;
- Land cover map;
- Soil maps;
- Orthophoto quads;
- Aerial photographs;
- Major land resource area map;
- Watershed project maps; and
- Well locations.

(e) Hydrologic Unit Maps.

Obtain a litho printed paper copy of the 8-digit state HU map prepared by the USGS Office of Water Data Coordination. Most SCS state offices developed an 11-digit hydrologic unit map on a small scale (generally 1:500,000) state base map. Some state agencies and district offices of the USGS Water Resources Division also have developed HU maps.

Use any of these maps as a reference to determine the general location of the new or redefined Watershed or Subwatershed hydrologic units, review the existing numbering system, and use any existing maps as a guide for planning and determining the level of mapping to be done.

304.21 Establishment of Watershed and Subwatershed HU Boundaries.

(a) General.

The delineation of the hydrologic unit boundary is the largest single factor affecting the accuracy and usability of the final map and digital data. Use professional judgment in determining the boundary locations. Establish hydrologic units using personnel with professional skills and / or experience in hydrology, resource conservation, cartography and resource mapping. Individuals must have good map reading skills. It is important to have a good understanding of how to recognize relief patterns, tops of hills, and ridges by interpreting contours. It is also important to be able to interpret drainage patterns, limits of drainage basins, and direction of drainage flow.

The fundamental requirement is to determine and map the most accurate location of the surface drainage boundaries based on hydrologic features on a map of precise scale that meets national map accuracy standards.

(b) Hydrologic Guidelines and Definitions for Determining HU Boundaries.

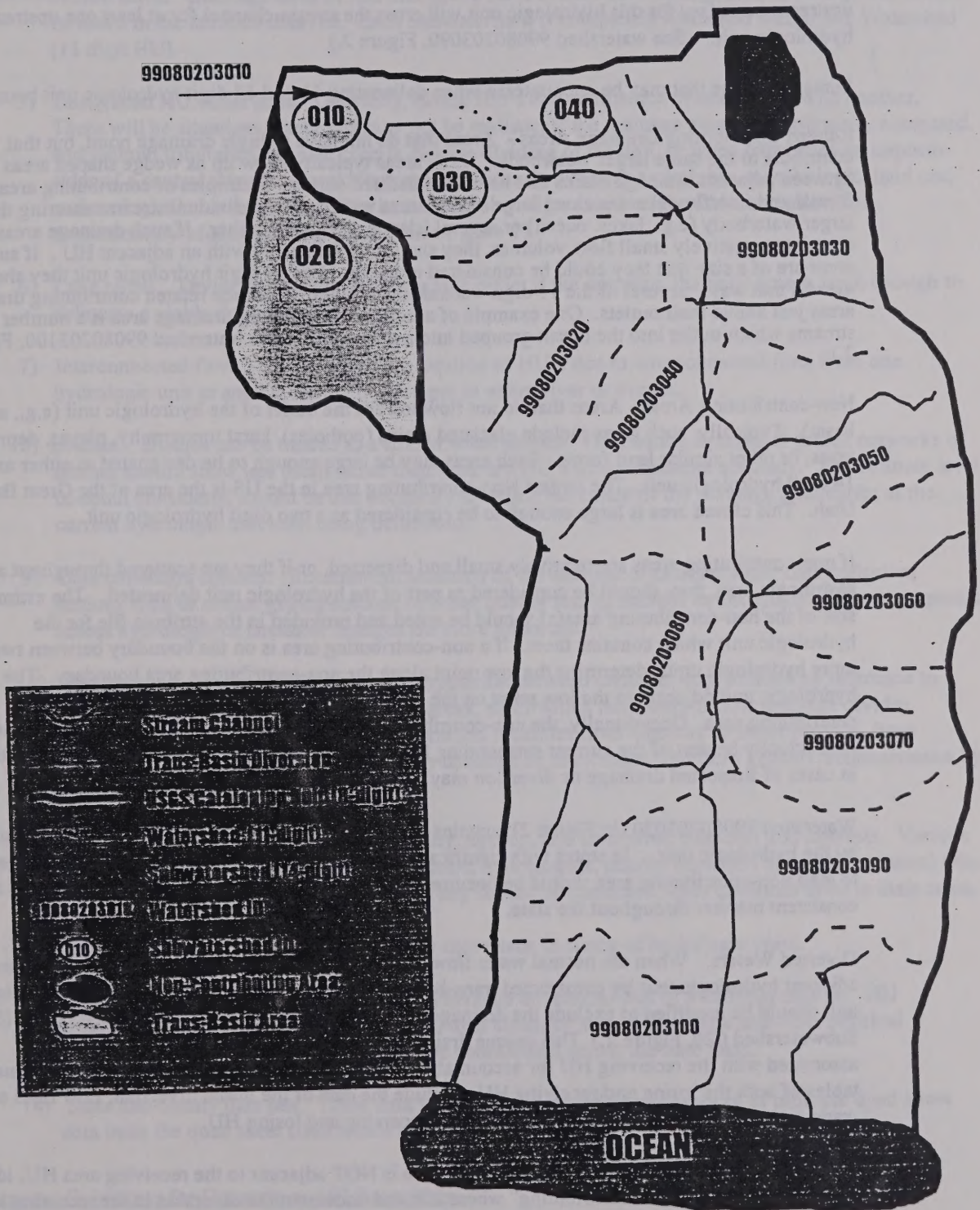
Use the following hydrologic related guidelines to determine the Watershed and Subwatershed hydrologic unit boundary locations. These guidelines are not all inclusive, variations however will generally be limited to those appropriate for unusual hydrologic or dissimilar hydrologic and or morphologic drainage area characteristics. The intent of defining these drainage units is to establish a base-line drainage boundary framework that has complete accountability of all area and surface water yield, is hydrologically consistent, and meets NRCS national mapping standards. The delineation should therefore be as simple as is practical and not favoring one agency, program or project. Program or special purpose drainage boundaries can be generated as needed for that purpose.

- 1) HU definition. An area of land above or upstream from a specific point on a stream (designated as the watershed mouth or outlet), which is defined by a hydrologic boundary that includes all of the source area that could contribute surface water runoff directly and indirectly to the designated outlet point. The HU may also contain associated surface areas such as related contributing drainage areas, non-contributing, and trans-basin diverted areas associated with the certain designated outlet point.

Earlier versions of the Watershed and Subwatershed delineations may have utilized administrative boundaries such as state and county or project lines to define HU's. The HU boundaries must be determined solely upon hydrologic features to obtain a homogeneous national seamless digital data layer.

- 2) Delineation of HU boundary. The traditional (or classic) hydrologic unit is the pure hydrologically defined surface water drainage area. It is delineated by starting from the designated outlet (a point on the single stream channel that drains this area) and proceeding to follow the highest elevation of land that divides the direction of water flow. This boundary will connect back with the designated outlet (see Watershed 99080203020 and Subwatershed 010, Figure 2). Boundary lines follow the middle of the highest ground elevation or halfway between contour lines of equal elevation. The HU boundary will cross the stream channel at the outlet. The selection of the outlet point is critical to the sizing of the area into the desired HU category, i.e. Watershed or Subwatershed.

Figure 2 - Typical HU Delineations and Coding



Along the main drainageway or on larger tributaries, the drainage area above the outlet may exceed the limits of the hydrologic unit level being delineated. In this case the drainage area can contain other hydrologic units of the same level embedded in the upstream drainage area, provided that the area remaining for this hydrologic unit is of the appropriate size and is contiguous. In these cases the upstream boundary for this hydrologic unit will cross the stream channel for at least one upstream hydrologic unit.. (See watershed 99080203090, Figure 2.)

Some situations that may be encountered when delineating 11 and 14 digit hydrologic unit boundaries.

Related Contributing Drainage Areas - Areas that do not have a single drainage point, but that contribute to the same larger waterbody. These areas typically show up as wedge shaped areas between adjacent drainage basins that have well defined outlets. Examples of contributing areas are frontal and interfluvial areas along large rivers, areas with similar individual streams entering the same larger waterbody (e.g., lakes, ocean) or several islands grouped together. If such drainage areas contribute relatively small flow volumes, they should be delineated with an adjacent HU. If such areas are of a size that they could be considered either an 11 or 14 digit hydrologic unit they should be viewed that way. Several of the 11 digit watersheds in Figure 2 include related contributing drainage areas just above their outlets. One example of a related contributing drainage area is a number of streams which outlet into the ocean grouped into a single HU. (See watershed 99080203100, Figure 2.)

Non-contributing Areas - Areas that do not flow toward the outlet of the hydrologic unit (e.g., a closed basin). Typically, such areas include glaciated plains (potholes), karst topography, playas, depression lakes, or other similar land forms. Such areas may be large enough to be designated as either an 11 or 14 digit hydrologic unit. The largest Non-contributing area in the US is the area of the Great Basin in Utah. This closed area is large enough to be considered as a two digit hydrologic unit.

If non-contributing areas are relatively small and dispersed, or if they are scattered throughout a hydrologic area, they should be considered as part of the hydrologic unit delineated. The estimated size of the non-contributing area(s) should be noted and provided in the attribute file for the hydrologic unit which contains them. If a non-contributing area is on the boundary between two or more hydrologic units, determine the low point along the non-contributing area boundary. The hydrologic unit adjacent to the low point on the boundary should be associated with this non-contributing area. Occasionally, the non-contributing area may be drained (via canal or pipeline) and thus actually be part of the current surrounding hydrologic unit or an adjacent one. Local investigation in cases of suspected drainage or diversion may be needed.

Watershed 99080203030 (in Figure 2) contains a large non-contributing area completely surrounded by the hydrologic unit. In states with significant amounts of non-contributing area, the criteria used to map non-contributing area should be documented. Non-contributing area should be mapped in a consistent manner throughout the state.

Diverted Waters. When the normal water flow from one HU is continuously discharged into an adjacent hydrologic unit by constructed trans-basin diversions, the drainage area of the water losing unit should be modified to exclude the drainage area to the point of the trans-basin diversion. (See Subwatershed 020, Figure 2.) This unique drainage area should be delineated separately and associated with the receiving HU for accountability of total drainage area included in the attribute tables of both the losing and receiving HU. Include the date of the initial diversion, flow rates and water rights as attribute information of both the receiving and losing HU.

If there is complete diversion and the diverted area is NOT adjacent to the receiving area HU, identify the diverted area as "non contributing" where it is and document the diversion in the receiving HU. If the diversion is partial, document in both the diverted and receiving HU's.

- 3) Watershed. Maintain a typical size for the Watershed (11-digit HU) drainage of 40,000 to 250,000 acres. Each Watershed is completely contained within one Subbasin (8 digit HU).
- 4) Subwatershed. Maintain a typical size for the Subwatershed (14-digit HU) drainage of 10,000 to 40,000 acres. Drainage areas of less than 3,000 acres should not be designated as 14 digit but should be noted in the attribute data file. Each Subwatershed is completely contained within one Watershed (11 digit HU).
- 5) Designated HU outlet point. Generally, divide HU's at a confluence of one stream with another. There will be situations where this may not be realistic; if the drainage area is exceptionally elongated, and without tributaries, but size criteria dictates dividing of the unit, or when tributaries on opposite sides of a central stream channel represent significantly different hydrologic, morphologic, land use, and ecological characteristics. The boundaries should be simple as possible, and allow full accountability of area, and water yield (See Figure 1).
- 6) Lake outlet. Divide hydrologic units at a lake outlet if the upstream drainage area is large enough to delineate a viable drainage unit.
- 7) Interconnected flow. Do not adjust the location of HU's due to interconnected flow from one hydrologic unit to another during high stages in either river or stream.
- 8) Ditches. Ditches can be treated as a stream when needed. Delineation in areas of grided networks of ditches should show less detail rather than arbitrary HU's of questionable accuracy. The ultimate level of detail considered should be that necessary to define the extent of the drainage boundaries at the current hydrologic unit level being delineated.
- 9) Data collection stations. Recommend selection of the location of existing water data collection stations such as stream gaging stations or water quality testing stations as designated delineation points unless hydrologic or landform features are more important.
- 10) Flat terrain. In areas of flat terrain, interpolation between contours may be done by reference to trails, old roads, or firebreaks in forested areas; all of which frequently follow drainage divides. Detailed information may be obtained in certain localities from highway or street profiles, from examination of aerial photographs, county drainage or ditch maps, and from ground reconnaissance by locally acquainted employees.
- 11) Local contacts. Consider local community, agency, and landowner concerns and interests. Various agencies have local representatives (engineers, hydrologists, district managers and water masters) who are familiar with special problem areas. They should be contacted when questions arise in their areas.
- 12) State contacts. Incorporate state agency data needs in sizing of hydrologic units.
- 13) National data set. Each state data set will become an integral part of a national data set. HU boundary lines must match within national map accuracy standards at state and other political boundary lines and coding of HU's must be coordinated across the state lines.
- 14) State and county data sets. These data sets can be produced as a composite of multiple quad sheet data once the quad sheet sized sheets have been digitized.

(c) Mapping Guidelines for Determining HU Boundaries.

Use the following mapping related guidelines for determining the hydrologic unit boundaries.

- 1) Landforms. Identify and include similar landforms in a HU. Use aerial photographs, topographic maps and the major land resource area maps for reference.
- 2) Remapping. Re-delineate and / or update the existing 8 and 11 digit boundaries to meet the resolutions of the new 1:24,000 quad maps. The 8 and 11 digit boundaries were previously mapped on smaller scale state and national base maps and cannot merely be transferred to the larger scale quad maps. Notify the USGS District office in the state if the 8-digit boundaries are questionable as to location. Correct the location on the larger scale quad maps. Use the added cartographic detail on the quad maps to more accurately locate the boundaries.
- 3) Existing digital data. Do not use existing digital hydrologic unit databases that were previously digitized from smaller scale state or national base maps with 1:24,000, or other scale quad maps. Overlaying or digitally combining digital data developed from small scale maps onto larger scale maps will result in differences in line location of the same features. The boundary locations must be re-mapped and digitized to conform to the more accurate and detailed quad maps.
- 4) Existing numbering system. Do not change the numbering of the USGS 8-digit HU's. This numbering system was established as a nationally uniform hydrologic unit coding system and cannot be changed. Also refer to the existing NRCS 11-digit numbering system, contained elsewhere in these instructions.
- 5) Existing NRCS 11-digit map. Most state offices already have a state HU map of Subbasin (8-digit) and Watershed (11-digit) boundaries. Many of these watershed scale maps were done on different and inaccurate base maps. These maps are not acceptable for digitizing but are good to use as a general reference in relocating the 11-digit hydrologic units onto the more accurate 1:24,000 quad maps.
- 6) Map coordination. Coordinate the mapping of HU's across county and state boundaries at state level. This is necessary to assure that a nationally consistent database is created. Refer to section 304.03 Responsibility, for additional information.
- 7) Topographic detail. Utilize the topographic detail (contours, elevations, drainage patterns) on the maps to accurately interpret and locate the hydrologic unit boundaries of Watersheds and Subwatersheds.
- 8) Digital hydrography and digital elevation data. The direction of drainage flow may be determined from digital hydrography and EPA river reach files and / or digital elevation models (DEM's). The 1:24,000 scale hydrography and transportation data are available from USGS National Mapping Division (NMD). NMD will complete the collection of hypsography, boundaries, and U.S. Public Land Survey System Data in 1995.

Maps generated from digital hydrography data with designated flow arrows would be helpful in delineating HU's. DEM's are being developed for the 1:24,000 quads but the current coverage is sparse. Discuss the feasibility of using this procedure and the availability of the data with the NRCS State GIS Specialist. Automated drainage area boundaries generated from DEM's can be used to preliminarily establish HU boundaries. All DEM established boundaries need to be independently checked on 1:24,000 (or other appropriate) scale maps. Largest DEM boundary differences will be found in areas of flat terrain.

(d) Mapping the HU Boundaries at 1:24,000 Scale.

- 1) Start by mapping the 8 and 11-digit HU's onto the 1:100,000 USGS quad paper maps. Mapping the HU's onto the 1:100,000 quad maps first provides a quick view of where the HU's are generally located and shows the level of detail. It also shows which 1:24,000 quad maps the hydrologic units need to be mapped on.

Coordinate the 11-digit preliminary delineation with all other states included in the Subbasin. This coordination should include: the locations of 11-digit outlet points; the size of the 11 digit areas; and the HUC sequence used within the Subbasin.

- 2) Re-compile the HU boundaries from the 1:100,000 quad maps to the USGS 1:24,000 quad maps. It is recommended that this be done by finding the boundary on the 1:100,000 map and visually locating the boundary onto the 1:24,000 quad maps. When transferring the boundaries, make refinements and adjustments to the boundary location to fit the more detailed contour intervals and drainage patterns on the 1:24,000 quad maps. Add the 14-digit Subwatersheds to the map after the 8 and 11-digit boundaries have been accurately located. Label each 11- and 14-digit area with the appropriate HUC.

If the maps are to be raster scan digitized, draft the boundaries onto an overlay that is taped or registered over the quad map. Place corner quadrangle ticks on the overlay and add neatlines. The ticks should be solid crosses about 0.20" in length, done using a 00 rapidograph pen. The neat lines should be a light color such as orange or yellow.

- 3) Use a color scheme to draft the hydrologic unit boundaries in order to provide easy identification of the Subbasin, Watershed and Subwatershed boundaries. Delineate the HU's with a color pencil. For example, map the 8-digit boundary in red, 11-digit in black, and 14-digit in green. Do not use blue as it reproduces poorly. Document what HU level each color represents on the base map.

If the boundaries are being transferred to a mylar overlay, show the boundaries and codes in black ink or black pencil. Draft the boundaries with consistent lines. Keep the lines dark with no skips or breaks. Use a drafting or art-type pencil, do not use regular lead pencils which smear on drafting film. A color other than black may be used provided that the scanner that will be used is sensitive to the color. The penciled line width should not exceed 0.025".

- 4) Edit the 1:24,000 quad map as described in Section 304.23, Quality Control. Match all boundaries at neatlines to adjoining maps.
- 5) In order to develop a consistent national data base of HU's - matching hydrologic unit boundary lines across state and administrative lines is essential and will require coordination at the state level. Differences in watershed delineations and attributes at 1:24,000 scale must be resolved. In the event a drainage unit lies in several administrative designations, each entity has the responsibility to delineate the hydrologic boundaries at the scale appropriate to all interests and to obtain mutual technical approval. Refer to section 304.03 Responsibility, for additional information.

(e) Recording HU Determinations.

Retain all maps, measurement data, and other information used to determine and map the hydrologic units as a permanent record. Keep a record or explanation of the methods, procedures, and maps used. Retain the original record at the state office. States may want to incorporate some of this information in their GIS database.

(f) Preliminary Acreage Determinations.

Preliminary or existing acreage determinations of HU's may be available from other sources. Identify these values as PRELIMINARY and correct or adjust the values after digitizing. Refer to section 304.21 (b) Hydrologic Guidelines and Definitions for Determining HU Boundaries, for typical and minimum sizes for 11- and 14- digit hydrologic units.

304.22 Assignment of HU codes to Watersheds and Subwatersheds.

(a) General.

The existing 8-digit USGS codes were established nationally and are to be used for these maps. Use the 11-digit codes (consistent with this instruction). This is also the starting point for coding the 14-digit Subwatershed boundaries

(b) Hydrologic Unit-Coding Procedure.

Each Watershed and Subwatershed is to be assigned a unique code (number) which are coordinated for a Subbasin across state boundaries. The HUC should not be complicated by trying to code hydrologic units as to their complete or partial presence within a county or presence within two or more counties or states.

The approach is to number the HUC's sequentially beginning upstream and proceeding downstream (for example starting at uppermost end of the drainage, code the first Watershed unit as 99080203010, with the next traditional watershed downstream coded as 99080203020). Reserve the last character position for coding later additions to the hierarchical scheme. While the need for later additions may not be anticipated when the delineations are originally done, the allowable size range for Watersheds and Subwatersheds must be considered. The ratio of the largest to smallest size Watershed is about 6:1 and largest to smallest Subwatershed is 4:1. Thus a large sized Watershed could be replaced with up to 6 smaller Watersheds and a large Subwatershed could be replaced with up to 4 small Subwatersheds. Therefore, in originally assigning HUC's the last three digits of an 11 or 14 digit HU would be coded as 010, 020, 030, etc.

304.23 Quality Control.

(a) Checking the Boundaries.

The mapped hydrologic unit boundaries should be checked at the originating office or by an experienced person outside the office. Two checks are recommended at the state, one by the area or field office and the second at the state office. The state and local persons should work directly with the adjoining state and local counterparts to achieve national map accuracy standards (NMAPS) matching across the administrative boundaries. All boundaries in a state do not have to be delineated before coordination occurs beyond state boundaries.

HU's that were difficult to delineate, especially in flat areas, may need to be field checked by local, state, or federal offices or by multi-agency teams. Hydrologic unit boundaries may be checked by representatives of other interested agencies or local groups before map reproduction, digitizing and distribution to the public.

(b) Map Edit.

- 1) Prepare an edit checklist for each quad sheet or map used. A table with all Watershed and Subwatershed HU codes contained on the map listed as the rows and at least the following topics as columns: boundary notes; HU code; edge matching and attribute list.
- 2) To help the editor, make notes on the 1:24,000 scale quad map about the establishment of certain boundaries. Make notes where local knowledge supersedes the topographic map. Use local sources to resolve the location of questionable unit boundaries.

- 3) Check the coding system for correctness, duplication, missing (non-consecutive) codes and proper codes across administrative or other lines when edge matching drainage areas.
- 4) Compare HU boundaries and codes to adjoining maps. Hydrologic unit boundaries which join adjacent maps must meet NMAPS at the map neatline. Check the joining of boundaries of previously mapped HU's at county and state boundaries.
- 5) Check for and note in the attribute data any data exceptions such as non-contributing and trans-basin flow areas within each HU boundary.

304.24 Quality Assurance

The completed and edited boundary mapping is to be reviewed by the National Cartography and Geospatial Center (NCG)). The NCG will be responsible to review the HU boundaries for adherence to this mapping standard particularly looking for mapping consistency and coordination across-state-lines. A letter will be returned to the State Conservationist covering the findings of the review and approval to proceed with digitizing.

SUB PART D - DIGITIZING HU's

304.30 Purpose.

This section establishes guidelines for digitizing HU boundaries which have been mapped using the methodology described in SUB PART C. These guidelines and standards apply to digitizing the HU boundaries from the 1:24,000 USGS quad maps.

- 1) Maintain the integrity and positional accuracy of the originally mapped HU boundaries;
- 2) Promote nationwide consistency in the quality and utility of the digital HU boundaries, and their compatibility with other digital resource data;
- 3) Create digital files suitable for use in geographic information systems (GIS) and the NRCS Field Office Computing System (FOCS);
- 4) Facilitate the management of HU's within a field and state office automation environment;
- 5) Facilitate the management, exchange and archiving of digital HU files both within and outside the NRCS; and
- 6) Encourage and expand the use of HU's for resource planning, management, analysis, decision making and reporting.

304.31 Digitizing Method.

Digitizing is the process of converting points, lines and area boundaries shown on maps into x, y coordinates (e.g. latitude and longitude, universal transverse mercator (UTM) or table coordinates). The two basic data structures used to do digitizing are vector and raster.

The vector data structure is the required method for developing the digital HU database. Vector digitizing is done by either manual or scan digitizing. Raster data that was obtained by scanning must be converted to the vector format for the HU database. Raster digitizing by scanning is only acceptable when the raster cell size allows for vectorization of the original line work in order to meet the digitizing specification. At 1:24,000 scale, the raster cell size (e.g. resolution) should be approximately 25 feet or smaller.

304.32 Map Materials Needed for Digitizing.

The following map materials and documents are needed for digitizing at the 1:24,000 scale:

- a) HU boundary map overlays (if used) with geographic control points identified.
- b) 1:24,000 paper (or mylar) quad maps with HU mapping.
- c) List of all the HUC's.

304.33 Digitizing Requirements.

After a map is digitized, all the individual line-segments must be linked together into a logical structure to define the individual polygons that represent HU's. This process is called topological structuring. The line-segments and HUC's of each data set must be topologically structured. The ability to overlay and use the HU geospatial database in a GIS requires a topological data structure. The Geographic Resource Analysis Support System (GRASS) Geographic Information System (GIS) or Line Trace Plus (LT Plus) digitizing software automatically generate topology.

(a) Geographic Control.

It is essential to establish precise geographic or geometric control prior to digitizing each map. Control is established through the map registration process. This procedure affects the positional accuracy of all features to be digitized. It is one of the more critical steps in the digitizing process.

Establish geographic control by using the four corners of the quad map. Using additional interior tick marks is desirable, but not mandatory. Record the projection coordinate system and map projection used with the digital data sets.

The geographic control points established at the four corners are used to:

- 1) Relate the map to the digitizing tablet and, in turn, all digitized locations on the HU quad map to their geographic positions on the earth's surface.
- 2) Convert digitized map coordinates from one projection system to another.
- 3) Join adjacent maps into a single county or state geospatial database.

The map neatline is explicitly entered and forms the maximum extent of the digital data set for each map sheet. HU boundaries are digitized as closed area polygons. HU boundaries that intersect the map neatline must have a node that lies on the neatline.

(b) HU Boundaries.

Digitize to the centerline of the HU boundary with a deviation of no more than 0.025" of the mapped HU boundary centerline. The number of coordinate pairs will be the minimum necessary to represent the HU boundaries within the 0.025" accuracy limit.

All beginning and ending points of each digitized HU boundary must connect at a common intersection point with another HU boundary or the map neatline.

(c) HUC's.

The HUC must be identical to the code shown on the original map. Position the code inside the HU polygon. Use the lower left corner of the first code as the text origin for horizontal placement. Insert additional codes within large HU's to improve the readability and identification of the data set and map. Areas on the map which are not mapped or not part of the HU project are to be labeled "NODATA".

The HUC is comprised of either 11 or 14 digits. The 11-digit HUC is to be used for the 1:100,000 scale and 11- and 14-digit for the 1:24,000 scale. The format for the HU code is as follows:

First 2 fields are the Region	01
Next 2 fields are the Sub-region	0108
Next 2 fields are the Accounting Unit (NRCS - "Basin")	010802
Next 2 fields are the Cataloging Unit (NRCS - "Subbasin")	01080204
Next 3 fields are the NRCS Watershed	01080204010
Next 3 fields are the NRCS Subwatershed	01080204010010

It is recommended that states with existing 10- or 13-digit HUC's convert to the 11- or 14-digit system.

The U.S. Environmental Protection Agency (EPA) River Reach File - 3 (RF-3) code, where available, for the outlet of each HU, should be included as an attribute of the digital basin representation.

(d) Adjoining Boundaries.

The HU boundaries ending at each map neatline are to be edge-matched to HU boundaries on adjoining maps. The adjoining boundary coordinates must match exactly. Check the adjoining maps prior to digitizing and revise if necessary to improve the boundary locations.

(e) Merging data sets into county or state coverage.

The NCG will archive the digitized 1:24,000 scale HU quad maps as merged state data sets. This will allow the national data set to be divided easily into either state or 8-digit hydrologic unit.

Using GIS, the data must be clipped to a state digital database boundary. Use the state boundaries directly from the quad sheet and included as digitized lines. The merging of digitized quad sheet lines into a state digital layer will require additional guidance. NCG will provide additional information which is not covered in this instruction.

304.34 Quality Control.

Quality control is a responsibility of the state office or location performing the digitizing. If the digitizing is performed by someone outside of NRCS, then the NRCS state office that contracted for or entered into an agreement for the digitization is responsible for quality control.

(a) Check Plot.

Make a computer check plot for each digitized quad sheet map. Generate the plot with either a ball pen or wet ink pen plotter using a 0.025" or less line width. Plot the map at the same scale and same map projection as the original digitized map. At the 1:24,000 scale the 2 ½ minute ticks should be plotted.

Place the check plot over the original HU map and compare the matching of lines, ticks and codes. Plot the map name and scale outside the map neatline.

(b) Edit.

Make a complete and detailed edit of the digitizing work. A preliminary edit is advised after digitizing the first two adjoining maps.

Assign a specialist on the state staff the responsibility for assuring that the digital data matches the original mapping. Look for the following during the editing process:

- 1) HU boundary placement according to the established mapping criteria and the original map;
- 2) Unconnected boundary lines, missing lines, or unclosed polygons;
- 3) Unacceptable line offsets or mismatching;
- 4) Missing, incorrect or duplicated HUC's;
- 5) Edge matching of HU boundary lines to adjoining maps;
- 6) Boundary overshoots and undershoots at the neatline; and
- 7) Appropriate entries have been made in the attribute file for each HU digitized.

304.35 Quality Assurance.

NCG will provide final quality assurance review and certification of digitizing work. Materials are generally provided for an entire state. Less than entire state data may be submitted for interim review if arrangements are made in advance.

(a) Materials Submitted.

All digital data will be submitted on 8 mm or 1/4 " cartridge tapes that are written with the UNIX tar command.

Materials submitted include for the assurance review are

- Digital line graph and attribute files;
- Metadata file; and
- Form SCS-CGI-019 requesting quality assurance assistance.

(b) Review.

The assurance review may only include a portion of the materials submitted for some aspects of the review process. Items included in the review:

- Media is readable and properly labeled;
- Ground based system for spatial data is Universal Transverse Mercator. Units are meters. Data are not shifted. Horizontal datum is the North American Datum of 1983. Spheroid is Geodetic Reference System of 1980;
- Topology is correct. Line segments join only at nodes and all defined areas are closed;
- Digital line graph and attribute file formats are correct and the files are properly named;
- Spatial data files meet the standards for USGS Digital Line Graph Optional format; and
- Metadata file is accurate and complete.

304.36 Data File Format.

All data files must be formatted in a Modified Digital Line Graph Optional (DLG-3) Format. The DLG-3 Optional

format is described in Appendix B of the U.S. Geological Survey, National Mapping Program, Circular 895-C, entitled Digital Line Graphs from 1:24,000-Scale Maps. A sample DLG data file is available in the Circular. In the near future the federal Spatial Data Transfer Standard (SDTS) will become mandatory. Recommend that metadata files for each data used be maintained for use in transition to the SDTS when it becomes official.

Comply to Sections 304.30 through 304.35 when providing data in the DLG-3 Optional Format.

The DLG-3 Optional Format as supported by the USGS requires the digital data to be in ground Universal Transverse Mercator (UTM) coordinates. NRCS requires, however that the final digital data be provided in latitude and longitude decimal degree values; three digits to the left and four digits to the right of the decimal (single precision, 4 byte, arithmetic). Longitude values west of 0 degree longitude must be recorded as negative values.

NRCS also requires that HU data be provided as two separate files: a HU area file, and a HU attribute file. The HU area file is a DLG-3 file. The HU attribute file is an appended flat ASCII file containing either the 11- or 14-digit codes for each unique HU polygon number.

The digital HU boundaries data set must match the map format of the USGS 1:24,000 quad maps.

(a) HU area file.

The HU area or polygon file contains DLG header records and DLG data records. Required data records include:

- Area identification records containing area centroid locations which serve as reference points for plotting boundaries of HU;
- Line identification records and coordinate string records containing all line work serving as HU boundaries; and
- Area-to-line linkage records identifying which lines belong to which polygons.

Note that DLG attribute code records, node identification records, and node-to-line linkage records are not required. They can be present but will not be used.

(b) HU attribute file.

This is an delimited ASCII file and contains at least one data record for each HU area or polygon. Each record consists of a left-justified identification number followed by a space and then the 11- or 14-digit HUC. The area identification number must match the unique area number in the DLG HU area file area identification record. The HUC matches the code shown on the HU quad map.

Other attribute data to include are:

- Date delineated;
- Date delineation (last revised), if needed;
- Identification of non-contributing areas in the HU (surface area, type - closed basin, sink hole, porous surface, etc., and extent - one or two large areas or scattered throughout); and
- Identification of trans-basin areas in the HU (surface area, flow type - pipeline, ditch, interflow, etc., which HU the area normally would belong to if no trans-basin flow.).

304.37 Digital Products.

(a) Acreage Calculations.

Develop acreage calculations and a total polygon count for each HU map data set calculated from the digitized map. Develop total acreage counts for each HUC. Acreage calculations for HU's may also be summarized by county, state, or project area. Archive the summaries at the state office.

Produce a computer listing of the acreage calculations. List acreage calculations numerically by HU types and areas not mapped (NO DATA). Calculate the acreage to the nearest 0.1 acre.

(b) Maintaining Digital Data.

Make two softcopy files of all data sets. Send one file set to the NCG for archival, storage, tape maintenance, re-formatting, plotting, and distribution. The other should be stored locally, preferably off site from the computer that contains the stored data.

(c) Distribution of Products.

NCG will provide the certified digital HU data sets for the national watershed and sub watershed data layer. NCG will support electronic access as well.

SUB PART E -Revisions and Updates

304.40 Maintenance and Updates

(a) Revision of Mapped Boundaries.

When hydrologic unit boundaries are revised, any acreage determinations which changed significantly are to be noted as "revised" when new data or maps are released. The revision date should also be included in the attribute file for each HU that has its boundaries revised or is renumbered.. The decision as to when a revised acreage measurement or map of the hydrologic boundaries is made is the responsibility of the state office. Coordinate the revision of HU's with other interested agencies.

SUB PART F - TERMS AND REFERENCES

304.60 Terms.

Attributes. These are the alpha or numeric text characteristics which describe a given spatial feature. Attributes are commonly stored in a relational database structure of flat ASCII file. Common attributes in a hydrographic database of streams would include stream name, length, and direction.

CatalogingUnit. The 4th level (and smallest in typical area) of drainage delineation of the 1974 Water Resources Council / USGS hierarchy of national HU's. This HU is coded with 8-digits. Minimum size is about 700 sq. miles (448,000 acres).

Contiguous. In drainage areas - physical features that occur with enough frequency and close enough in proximity to alter hydrologic characteristics of the basin or watershed.

Contour. A line on the map in which all points are at the same elevation.

Coordinates. Linear or angular quantities that designate the position of a point, line or area in relation to a given coordinate system. In a 2-dimensional system, x and y are used to designate coordinates.

Edge matching. A procedure used to adjust features along one or both sides of a common map edge (neatline) to create a continuous or seamless product when the maps are joined.

Geographic projection coordinates. A coordinate system for defining the position of points on the earth's surface (e.g. latitude and longitude or UTM).

Geographic Information System (GIS). A computer system designed to collect, manage, manipulate, analyze, and display spatially referenced data. A GIS includes both attribute and geospatial data. The primary components of a GIS are software, hardware, data and trained technicians.

Hydrologic Unit (HU). An area of land upstream from a specific point on a stream (designated as the mouth or outlet), which is defined by a hydrologic boundary that includes all of the source area that could contribute surface water runoff directly and indirectly to the designated outlet point. The HU may also contain associated surface areas such as related contributing drainage, non-contributing, and trans-basin diverted areas associated with the certain designated outlet point. It may also have one or more of the same level hydrologic units completely contained within the upstream drainage area.

Earlier versions of the Watershed and Subwatershed delineations may have utilized administrative boundaries such as state and county or project lines to define HU's. The HU boundaries must be determined solely upon hydrologic principles to obtain a homogeneous national seamless digital data layer.

Hydrologic Unit Code (HUC). The identifier of a specific HU. It is determined by an established system of assigning numbers and alpha characters in a specified order and in different fields of a composite code (Watershed and Subwatershed, 11 and 14) that represents specific subdivisions of the nations drainage at different levels of detail or size. The following is composed of the USGS standard for identifying the first four levels of delineation plus the NRCS method for the next two levels of sub-division:

First 2 fields are the Region	01
Next 2 fields are the Sub-region	0108
Next 2 fields are the Accounting Unit (NRCS - "Basin")	010802
Next 2 fields are the Cataloging Unit (NRCS - "Subbasin")	01080204
Next 3 fields are the NRCS Watershed	01080204010
Next 3 fields are the NRCS Subwatershed	01080204010010

It is recommended that states with existing 10 digit HUC's convert to the 11-digit system and those with 13-digit convert to the 14-digit system.

Mylar. A transparent stable base polyester photographic film designed for mapping.

Neatline. The lines on a map that serve as the outside border or limits of the map sheet.

Non-contributing. Areas that do not flow toward the outlet of the hydrologic unit (e.g., a closed basin). Typically, such areas include glaciated plains (potholes), karst topography, playas, depression lakes, or other similar land forms.

Paper Copy Quad Map. A USGS litho printed paper quad map with the standard topographic, drainage, and cultural features at scales of 1:100,000 or 1:24,000.

Polygon. A closed loop of x, y coordinate pairs that define the boundary of an area. The polygon is often defined by a series of straight lines, arcs, or combinations of both. Examples are watersheds and soil areas.

Raster Digitizing. Point, line, and area features from a map are stored as values in the cells or pixels of a uniform grid.

River Basin. A drainage unit defined by the hydrologic boundary that feeds a river. This is not a standard HU designation.

Subwatershed. A delineated HU depicting the location of a drainage area that is typically 10,000 to 40,000 acres in size. (It can, though, be as small as 3,000 acres.) The 6th division level of the nation's drainage. Represented by extending the 11-digit HUC to 14-digits.

Topology. A mathematical method used to define spatial relationships. Topology defines the location of geographical phenomena relative to each other, but is independent of distance or direction. Topology depicts connectivity of one entity to another. Topology is required for proper associations to be made among features such as arc, nodes, points, and polygons and their attributes.

Vector digitizing. Point, line, and area features from a map are converted to x, y coordinates. A point is represented by a single coordinate, a line by a string of coordinates and an area or polygon by a series of lines making up the polygon.

Watershed. The 5th level of HU delineation. Continues the 1974 Water Resources Council / USGS fourth level hierarchy of HU's to the next smaller useful size. This is represented by extending the 8-digit HUC to 11-digits. Typical size is 40,000 to 250,00 acres.

304.61 References.

Chapter 3 - Common Water Unit, Draft Integrated Resource Inventory User's Guide, USFS, July, 27, 1993.

Hydrologic Unit Maps. A USGS Water Supply Paper No. 2294. Provides history and development of HU's and the 8-digit HU maps. Discusses technical criteria, cataloging, uses and compilation guidelines.

National Soil Survey Handbook, Chapter 4, Map Compilation and Chapter 5 Digital Data Capture

State Hydrologic Unit Maps. A USGS published brochure describing the 8-digit maps.

USGS digital cartographic data standards. Digital line graphs from 1:24,000-scale maps. Circular 895-C, USGS. 1983.

Appendix A - Hydrologic Unit Boundary Metadata Template

Identification Information

Citation

Originator: U.S. Department of Agriculture, Natural Resources Conservation Service

Publication Date ____ (1) ____

Title: ____ (2) ____

Publication Information: Fort Worth, Texas

Publisher: U.S. Department of Agriculture, Natural Resources Conservation Service

Description

Abstract: This data set is a digital hydrologic unit boundary that is at the Watershed (11-digit) or Subwatershed (14-digit) level as appropriate. The data set was developed by delineating the boundary lines on base maps or overlays and digitizing the delineated lines. Digital Elevation Model data may have been used in part of the process to establish preliminary boundaries.

This data set consists of geo-referenced digital map data and attribute data. The map data are in 7 1/2 minute quadrangle format and include complete coverage of the entire quadrangle. All area within the quadrangle is contained in one and only one hydrologic unit boundary at this level. The hydrologic unit ID code attached to each delineated polygon is linked to the attribute data which contains information on non-contributing area and trans-basin flow.

Purpose: The Watershed and Subwatershed hydrologic unit boundaries provide a uniquely identified and uniform method of subdividing large drainage areas. These smaller sized hydrologic units (up to 250,000 acres) are useful in many programs supported by the Natural Resources Conservation Service and others.

Supplemental Information: Digitized hydrologic unit boundaries are also available as a data set for a complete state including sub divisions for counties.

Time Period of Content

Single Data/Time

Calendar Date: ____ (3) ____

Currentness Reference: publication date

Status

Progress: Complete

Maintenance and Update Frequency: As needed

Spatial Domain

Bounding Coordinates

West Bounding Coordinate: ____ (4) ____

East Bounding Coordinate: ____ (5) ____

North Bounding Coordinate: ____ (6) ____

South Bounding Coordinate: ____ (7) ____

Keywords

Theme

Theme Keyword Thesaurus: None

Theme Keyword: hydrologic units

Theme Keyword: Watershed boundary
Theme Keyword: Subwatershed boundary

Place

Place Keyword Thesaurus: Counties and County Equivalents of the States of the United States and the District of Columbia (FIPS Pub 6-3)

Place Keyword: _____(8)_____

Place Keyword: _____(8)_____

Place Keyword Thesaurus: USGS Topographic Map Names Data Base

Place Keyword: _____(9)_____

Access Constraints: None

Use Constraints: The U.S. Department of Agriculture, Natural Resources Conservation Service, should be acknowledged as the data source in products derived from these data.

This data set is to be used as a primary reference source. This is public information and may be interpreted by organizations, agencies, units of government, or others based on needs; however, they are responsible for the appropriate application. Federal State, or local regulatory bodies are not to reassign to the Natural Resources Conservation Service any authority for the decisions they make.

Photographic or digital enlargement of these maps to scales greater than that at which they were originally delineated can cause misrepresentation of the data. If enlarged, the maps will not include the fine detail that would be appropriate for mapping at the small scale. Digital data files are periodically updated. Files are dated, and users are responsible for obtaining the latest version of the data.

Point of Contact**Contact Organization Primary**

Contact Organization: U.S. Department of Agriculture, Natural Resources Conservation Service

Contact Position: _____(10)_____

Contact Address

Address Type: mailing address

Address: _____(11)_____

City: _____(12)_____

State or Province: _____(13)_____

Postal Code: _____(14)_____

Contact Voice Telephone: _____(15)_____

Contact Facsimile Telephone: _____(16)_____

Contact TDD/TTY Telephone: 202 720 7808 (Office of Public Affairs)

Cross Reference:**Citation**

Originator: U.S. Department of Agriculture, Natural Resources Conservation Service

Publication Date: _____(17)_____

Title: _____(18)_____

Geospatial Data Presentation Form: table, map

Description:

Abstract: The digitized hydrologic units provide area extent of drainage patterns at the appropriate level of detail (Watershed or Subwatershed). Such areas are useful in planning, design, and/or evaluation of water quality and water quantity.

Purpose: The base map provides the basis and media on which the extent of the hydrologic units was delineated.

Data Quality Information

Attribute Accuracy

Attribute Accuracy Report: Polygon identifiers are manually checked with the original base map using the attribute file. Verification on polygon identification continuity on each side of a neatline is done visually on the screen as adjacent quad representations are assembled into larger area data layers.

Logical Consistency Report: Certain node/geometry and topology (GT) polygon/chain relationships are collected or generated to satisfy topological requirements. (The GT-polygon corresponds to a hydrologic unit or a portion of a hydrologic unit at the edge of a quadrangle sheet.) Some of these requirements include: chains must begin and end at nodes, left and right GT-polygons are defined for each chain element and are consistent throughout, and the chains representing the limits of the file (neatline) are free of gaps. The tests of logical consistency are performed using vendor software. The neatline is generated by connecting the explicitly entered four corners of the digital file. All data outside the enclosed region are ignored and all data crossing geographically straight lines are clipped at the neatline. Neatline straightening aligns the digitized edges of the digital data with the generated neatline (i.e., with the longitude/latitude lines in geographic coordinates). All internal polygons are tested for closure with vendor software and are checked on hard copy plots. All data are checked for common boundary lines (i.e., adjacent polygons with the same label). Quadrangles are edge matched within the Subbasin area and edge locations generally do not deviate from centerline more than 0.01 inches.

Completeness Report:

_____ (19) _____

Positional Accuracy

Horizontal Positional Accuracy

Horizontal Positional Accuracy Report: The accuracy of these maps is generally based on the contour information or DEM data available for the base maps. Such data may be supplemented with site visits to locate ridge lines for hydrologic unit boundaries in flat terrain areas, changes in drainage patterns due to man's activities. The differences in positional accuracy between the hydrologic unit boundaries and their digitized map locations is unknown.

Hydrologic unit boundaries generally were digitized within 0.01 inches of their locations on the digitizing source. The digital map elements are edge matched against the data for the adjacent quadrangle. Edge match locations generally do not deviate from centerline to centerline by more than 0.01 inches.

Lineage

Source Information

Source Citation

Originator: _____ (20) _____

Publication Date: _____ (21) _____

Title: _____ (22) _____

Geospatial Data Presentation Form: _____ (23) _____

Publication Information

Publication Place: _____ (24) _____

Publisher: _____ (25) _____

Source Scale Denominator: _____ (26) _____

Type of Source Media: _____ (27) _____

Source Time Period of Content

Single Date/Time

Calendar Date: _____ (28) _____

Source Currentness Reference: _____ (29) _____
Source Citation Abbreviation: _____ (30) _____
Source Contribution: _____ (31) _____

Process Step

Process description: _____ (32) _____
Process Date: _____ (33) _____
Source Used Citation Abbreviation: _____ (34) _____

Spatial Reference Information**Horizontal Coordinate System Definition****Planar**

Grid Coordinate System Name: Universal Transverse Mercator

Universal Transverse Mercator

UTM Zone Number: _____ (35) _____

Scale Factor at Central Meridian: 0.9996

Longitude of Central Meridian: _____ (36) _____

Latitude of Projection Meridian: 0.0

False Easting: 500000

False Northing: 0.0

Planar Coordinate Information

Planar Coordinate Encoding Method: coordinate pair

Coordinate Representation

Abscissa Resolution: _____ (37) _____

Ordinate Resolution: _____ (38) _____

Planar Distance Units: meters

Geodetic Model

Horizontal Datum Name: North American Datum of 1983

Ellipsoid Name: Geodetic Reference System 80

Semi-major Axis: 6378137.0

Denominator of Flattening Ratio: 298.257

Entity and Attribute Information**Overview Description**

Entity and Attribute Overview: Hydrologic Unit delineations are closed polygons that encompass all area draining toward the lowest point (called outlet) in the polygon. Because of nominal sizes for the different hydrologic unit level: Watershed (40,000 to 250,000 acres) and Subwatershed (3,000 minimum, generally 10,000 to 40,000 acres), some polygons do not include all areas up to the drainage divide but all areas to one or more other upstream hydrologic units. A unique hydrologic unit code is used to identify each hydrologic unit. The Watershed hydrologic unit codes start with the 8-digit Subbasin (Cataloging Unit) number that contains the Watershed. Likewise the Subwatershed hydrologic unit codes start with the 11-digit Watershed number that contains the Subwatershed.

A map unit symbol uniquely identifies each closed polygon. Each symbol is linked to a hydrologic unit code. The uniqueness of hydrologic unit codes while applying to hydrologic units does not carry over to polygons. This is due to some hydrologic units crossing neatlines but polygons not crossing such lines. Two or more polygons on the same quadrangle may point to the same hydrologic unit code, as the connecting polygon could be on the adjacent polygon.

Attribute data associated with a hydrologic unit code includes:

- non-contributing area (acres);
- type of non-contributing area (number of areas, scatter throughout);
- trans-basin areas inflowing to hydrologic unit;
 - trans basin area (acres);
 - trans basin area originating hydrologic unit code; and
- notes concerning delineation of hydrologic unit boundary.

Entity and Attribute Detail Citation

U.S. Department of Agriculture. 199x. Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit Boundaries. Natural Resources Conservation Service; National Instruction 170-304 (Revised)

Detail Description

Entity Type

- Entity Type Label:
- Entity Type Definition:
- Entity Type Definition Source:

Attribute

- Attribute Label:
- Attribute Definition:
- Attribute Definition Source:

Attribute Domain Values:

- Codeset Name: Codeset Source:

Distribution Information

Distributor

Contact Organization Primary

Contact Organization: U.S. Department of Agriculture, Natural Resources Conservation Service,
National Cartographic and GIS Center

Contact Address

Address Type: mailing address
Address: P.O. Box 6567
City: Fort Worth
State, Parish or Province: Texas
Postal Zone: 76115

Contact Voice Telephone: 817 334 5559

Contact Facsimile Telephone: 817 334 5469

Resource Description: _____(39)_____ HU Boundary

Distribution Liability: Although these data have been processed successfully on a computer system at the U.S. Department of Agriculture, no warranty expressed or implied is made by the agency regarding the utility of the data on any other system, nor shall the act of distribution constitute any such warranty. The U.S. Department of Agriculture will warrant the delivery of this product in computer readable format, and will offer appropriate adjustment of credit when the product is determined unreadable by correctly adjusted computer input peripherals, or when the physical medium is delivered in damaged condition. Request for adjustment of credit must be made within 90 days from the date of this shipment from the ordering site.

The U.S. Department of Agriculture, nor any of its agencies are liable for misuse of the data. Nor is it liable for damage, transmission of viruses, or computer contamination through the distribution of these data sets.

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To file a complaint, write the Secretary of Agriculture, U.S. Department of Agriculture, Washington, D.C. 20250, or call (202) 720-7327 (voice) or (202) 720-4107 (TDD). USDA is an equal opportunity employer.

Standard Order Process

Digital Form

Digital Transform Information

Format Name: DLG

Format Version Date: ____ (40) ____

Format Specification: Optional

Format Content Information: spatial and keys

Transfer Size: ____ (41) ____

Digital Form

Digital Transform Information

Format Name: ASCII

Format Specification: Optional

Format Content Information: keys and attributes

Transfer Size: ____ (42) ____

Digital Transfer Option

Off-line Option

Off-line Media: 8 mm cartridge tape

Recording Capacity

Recording Density: 2.3

Recording Density Units: gigabytes

Recording Format: tar

Digital Transfer Option

Off-line Option

Off-line Media: 1/4-inch cartridge tape

Recording Capacity

Recording Density: 150

Recording Density Units: megabytes

Recording Format: tar

Fees: The charge for one data set is \$XX.XX. A data set is one hydrologic unit boundary area in full quadrangle format and includes both spatial and attribute data.

Ordering Instructions: Call or write to organization listed under Distributor. Spatial line data are in DLG-3 optional format. Digital line graph files contain area records. A conversion legend is provided for each digital line graph file. Hydrologic unit codes and information concerning the hydrologic unit area are available in a companion ASCII attribute file.

Turnaround: 10 working days

Metadata Reference Information

Metadata Date: 19950417

Metadata Review Date: 19950417

Metadata Future Review Date: 19960501

Metadata Contact

Contact Organization Primary

Contact Organization: U.S. Department of Agriculture, Natural Resources Conservation Service

Contact Position: GIS Specialist

Contact Address

Address Type: mailing address

Address: _____ (43) _____

City: _____ (44) _____

State or Province: _____ (45) _____

Postal Code: _____ (46) _____

Contact Voice Telephone: _____ (47) _____

Contact Facsimile Telephone: _____ (48) _____

Metadata Standard Name: Content Standards for Digital Geospatial Metadata

Metadata Standard Version: 19940608

Explanation of Template Metadata Numbered Elements

Numbers in Identification Information Section

Citation -

- 1 Publication Date - The date when the data set was published or otherwise made available for release. Enter the year (YYYY) the data is submitted for archiving and distribution. Example - Publication Date: 1995
- 2 Title- The name by which the data set is known. Enter the complete name and detail level of the hydrologic unit area or state included. Examples- Title -99080203040 Podunk Creek or 11-digit HUs for Maryland

Time Period of Content -

3. Calendar Date - The year (YYYY) the data set is submitted for archiving and distribution. This is the same as the entry for Publication Date. Example - Calendar Date: 1995

Spatial Domain-

Bounding Coordinates - The limits of a data set expressed by latitude and longitude values in the order: western most; eastern most; northern most and southern most. The bounding coordinates are for the hydrologic unit area or state boundary.

4. West Bounding Coordinate - Western most coordinate of the coverage limit expressed in longitude (decimal degrees). Example - 93.328
5. East Bounding Coordinate - Eastern most coordinate of the coverage limit expressed in longitude (decimal degrees). Example - 91.328
6. North Bounding Coordinate - Northern most coordinate of the coverage limit expressed in latitude(decimal degrees). Example - 41.328
7. South Bounding Coordinate - Southern most coordinate of the coverage limit expressed in latitude(decimal degrees). Example - 39.328

Keywords -

8. Place Keyword - The name of the state(s) that include the data set. Enter multiple states as separate entries.
Example - Place Keyword: Nebraska
Place Keyword: South Dakota
- 9 Place Keyword - The name of the quadrangle for the data set. Enter the USGS quadrangle name and number from the National Topographic Map Names data base. The quadrangle names and numbers are found in _____ . Example - Hartford Quadrangle (4122N09322W)

Point of Contact -

- 10 Contact Position - The job title or role of the individual in the state that should be contacted concerning the content of the data set. Example - Contact Position: GIS Specialist

11. Address - The street address or box number for the Contact Position. Example - Address: 111 Main Street, Room 15
12. City - The city name for the Contact Position. Example - City: Springfield
13. State or Province - The name of the state for the Contact Position. Example - State or Province: Ohio
14. Postal Code - The ZIP code for the Contact Person. Example - Postal Code: 44444-5678
15. Contact Voice Telephone - The telephone number (including area code) for the Contact Position. Example - Contact Voice Telephone: (410) 555-1234
16. Contact Facsimile Telephone - The FAX machine that services the Contact Position. Example - Contact Facsimile Telephone: (410) 555-5678

Cross Reference - Repeat entire section for additional references.

17. Publication Date - The date when the data set was published or otherwise made available for release. Enter the year (YYYY) the data is submitted for archiving and distribution. Example - Publication Date: 1995
18. Title - The name by which the data set is known. Enter the complete name and detail level of the hydrologic unit area or state included. Examples - Title -99080203040 Podunk Creek or 11-digit HUs for Maryland

Numbers in Data Quality Information Section

Lineage - Information about the events, parameters, and source data which constructed the data set, and information about the responsible parties. This section can be repeated for additional sources.

19. Completeness Report: Information concerning any variation from the standard criteria or definitions used in creating the data set.
20. Originator: The name of the organization or individual that developed the data set. Example - Originator: U.S. Geological Survey
21. Publication Date - The date when the data set was published or otherwise made available for release. Enter the year (YYYY) the data is submitted for archiving and distribution. Example - Publication Date: 1995
22. Title - The name by which the data set is known. Enter the complete name and detail level of the hydrologic unit area or state included. Examples - Title -99080203040 Podunk Creek or 11-digit HUs for Maryland
23. Geospatial Data Presentation Form - The mode in which the geospatial data is presented. Example - Geospatial Data Presentation Form: topographic quadrangle map
24. Publication Place - The name of the city and state where the data set was published or released. Example - Beltsville, Maryland
25. Publisher - The name or the organization or individual that published the data set. Example - Natural Resources Conservation Service
26. Source Scale Denominator - The denominator of the representative fraction of a map. Example - Source Scale Denominator: 24000
27. Type of Source Media - The medium of the source data. Generally this will be either "paper" or "stable base material". Example - Type of Source Media: paper

28. Calendar Date - Year (YYYY) in which the source data was collected or represents. Example - Calendar Date: 1993

29. Source Currentness Reference - The basis on which the source time period of content information of the source data set is determined. Generally this will be based on when the boundaries were delineated on the map. Free form text field. Example - Source Currentness Reference: map delineation

30. Source Citation Abbreviation - The short form alias for the source citation. Example - Source Citation Abbreviation: NRCS

31. Source Contribution - A brief statement identifying the information contributed by the source to the data set. Generally "map delineation", "digitize map", "financial support", and / or "field verify" would be appropriate. Example - Source Contribution map delineation and field verify

Process Step - Information about a single event. This section can be repeated for additional steps.

32. Process Description - An explanation of the event and related parameters or tolerances. Free form text. Example - Process Description: Site verification of trans-basin outlet location in HU 99637621040

33 Process Date - Year (YYYY) in which the Process Description was carried out. Example Process Date: 1994

34 Source Used Citation Abbreviation - The Source Citation Abbreviation for the group or individual that performed the Processing Step. Example - Source Used Citation Abbreviation: NRCS

Numbers in Spatial Reference Information Section

Spatial Reference Information is the description of the reference frame for and the means to encode coordinates in the data set..

Horizontal Coordinate System Definition

35. UTM Zone Number - The identifier for the UTM zone covered by this data set. For multiple zones, use a separate entry for each. Example - UTM Zone Number: 15
UTM Zone Number: 16

36. Longitude of Central Meridian - The line of longitude at the center of a map projection generally used as the basis for constructing the projection. Each UTM zone covers 6 degrees in longitude. Consider UTM zone 13 which begins at -102 degrees and ends at -108 degrees. The longitude of central meridian is the center of the zone or -105. Example - Longitude of Central Meridian: -105

37. Abscissa Resolution: The minimum (nominal) distance between the "x" or column values of two adjacent points, expressed in Planar Distance Units of measure. The resolution is dependent upon the source map scale.

Scale Abscissa Resolution

1:12,000.305

1:15,840.402

1:20,000.51

1:24,000.61

Example - Abscissa Resolution: .61

38. Ordinate Resolution: The minimum (nominal) distance between the "y" or row values of two adjacent points, expressed in Planar Distance Units of measure. The resolution is dependent upon the source map scale.

Scale Ordinate Resolution

1:12,000.305

1:15,840.402

1:20,000.51

1:24,000.61

. Example - Ordinate Resolution: .61

Numbers in Distribution Information Section

Distribution Information - Information about the distributor of and options for obtaining the data set.

39. Resource Description - The identifier by which the distribution knows the data set. Example - Resource Description: Podunk Quadrangle, 11 digit HU Boundary

Standard Order Process -

40. Format Version Date - The version data (YYYYMMDD) for the format of the data set. This date is in line 1 of the DLG header. Example - Format Version Date: 19920508

41. Transfer Size - The size (or estimated size) in megabytes of the transferred digital data set. This is the sum of all DLGs in the data set. Example - Transfer Size: 14.4

42. Transfer Size - The size (or estimated size) in megabytes of the transferred attribute data set. This is the sum of all attribute tables in the data set. Example - Transfer Size: 8.3

Numbers in Metadata Reference Information section

Metadata Content -

43. Address - The street address or box number for the Contact Organization. Example - Address: 111 Main Street, Room 15

44. City - The city name for the Contact Organization. Example - City: Springfield

45. State or Province - The name of the state for the Contact Organization. Example - State or Province: Ohio

46. Postal Code - The ZIP code for the Contact Person. Example - Postal Code: 44444-5678

47. Contact Voice Telephone - The telephone number (including area code) for the Contact Organization. Example - Contact Voice Telephone: (410) 555-1234

48. Contact Facsimile Telephone - The FAX machine that services the Contact Organization. Example - Contact Facsimile Telephone: (410) 555-5678

1. The purpose of this document is to provide a framework for the development of a...
2. The document is organized into the following sections:
- 3. Introduction
 - 4. Objectives
 - 5. Scope
 - 6. Definitions
 - 7. Requirements
 - 8. Design
 - 9. Implementation
 - 10. Testing
 - 11. Maintenance
 - 12. Conclusion
13. The document is intended for use by the following parties:
- 14. The project manager
 - 15. The project sponsor
 - 16. The project team
 - 17. The project steering committee
 - 18. The project steering committee
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